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WASTE HEAT FROM STEAM-ELECTRIC GENERATING PLANTS USING FOSSIL FUELS AND ITS CONTROL

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
CINCINNATI, OHIO

MAY 1968

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FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

WASTE HEAT

from

STEAM-ELECTRIC GENERATING PLANTS

USING FOSSIL FUELS

and

ITS CONTROL

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MAY 1968

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PURPOSE OF THE REPORT

This report was originally written for a study prepared by the Program Review and Evaluation Staff, Office of Program Plans and Development, of the Federal Water Pollution Control Administration, Washington, D. C., entitled - "Cost of Clean Water".

In this study, waste heat from the steam-electric generating plants using fossil fuel as listed in Federal Power Commission's 1965 Report, was assessed and the cost for treating the waste heat was estimated. Since then, the report has been revised to make it a "source" publication.

This report is intended to be used as a starting point and NOT as a "manual" or "guide," and is written primarily for sanitary engineers engaged in the field of water pollution control. Various heat cycles and alternative methods of power production are dealt with in some detail since the author feels that, unless the processes involved in power production are understood clearly, it may be difficult to provide suitable methods of curbing thermal pollution from these sources. The readers are referred to a standard textbook on Thermodynamics for details on steam cycles. This report also gives a summary of the effects of variations in temperature on rates of

chemical reactions and aquatic life. The readers are referred to, "Temperature and Aquatic Life," Laboratory Investigations Series - Number Six, Federal Water Pollution Control Administration, Cincinnati, Ohio, August 1, 1967.

SUMMARY

1. Excessive increases or reductions in ambient water temperature by other than climatological causes can be defined as "thermal pollution." Major waste heat-producing industries are: fossil fuel (oil, gas and coal), and nuclear power generating plants, steel mills, petroleum refineries, chemical plants, pulp and paper mills and distilleries.

2. An increase in stream temperature reduces its waste assimilation capacity. As water temperature increases, the D O saturation value decreases and the rate at which oxygen is removed by organic wastes increases more rapidly than the rate at which oxygen is supplied by reaeration.

3. Steam-electric generation has increased from 7.1 billion kwh in 1912 to 603.3 billion kwh in 1960. The estimated generation for 1970 and 1980 are 1,600 and 1,800 billion kwh respectively

4. The average National net heat rates (quantity of heat required to produce one kilowatt-hour of electricity) for fossil fuel power plants have decreased from 25,000 BTU/KWH in 1925 to 10,558 BTU/KWH in 1962. The estimated average

net heat rate for 1980 is 8,900 BTU/KWH. Similar trends in net heat rate reductions are observed for nuclear power plants also, the values being 11,946 BTU/KWH in 1960 and about 10,000 BTU/KWH in 1967. The estimated net heat rate for 1971 is 8,800 BTU/KWH.

5. Thermal pollution from steam-electric generating plants is caused by the heat, rejected from waste steam to cooling water, that is discharged to the stream. Condensers, feedwater heaters, superheaters and reheaters can decrease the amount of heat rejected to the cooling water.

6. Estimated total heat discharged in 1965 by 514 steam-electric generating plants was 4,235 ~~billion~~ trillion BTU's.

7. Estimated cooling water requirements for 514 plants are:

Temperature Rise in Cooling Water	Cooling Water Requirements Trillion Gallons per Year
10°F.	49.2
12°F.	41.0
13°F.	37.4
15°F.	32.8
20°F.	

8. Nuclear power plants reject 40 to 50 percent more heat than the fossil fuel power plants and, therefore, require more cooling water than fossil fuel plants.

9. Evaporative and non-evaporative devices can be used to reduce the temperature of the cooling water. These are cooling ponds, spray ponds, and natural or induced draft cooling towers. These evaporative devices generally cause water losses. The air-cooled heat exchanger is an example of a non-evaporative cooling device.

10. The total estimated capital costs of mechanical draft cooling towers for 504 plants are:

Range	Total Capital Cost of Mechanical Draft Towers	Cost/KW
10° F.	$665,000,000	$ 4.02
15° F	$594,000,000	$ 3.59
20° F	$533,000,000	$ 3.22

11. Power production by methods that do not use a steam cycle causes less thermal pollution. Such methods in commercial use include gas turbines, diesel engines and hydro-electric generation. Thermo-electric generation, thermionic generators, fuel cells, magnettohydrodynamic generators and fusion reactors are in the developmental stage

SECTION I

INTRODUCTION

Excessive increases or reductions in ambient water temperature by other than climatological causes can be defined as "thermal pollution". Heat, then, is a pollutant when added to, or removed from, a body of water in quantities that alter biochemical reactions, damage aquatic life or otherwise degrade water quality. Heat can be expressed in terms of temperature, in British Thermal Units (BTU's), or in calories (Cals.).* One BTU is defined as the quantity of heat required to raise the temperature of one pound of water, one degree Fahrenheit at, or near, its point of maximum density (39.1° F.)(1).

In the Power Industry, heat wasted through cooling water is expressed in terms of BTU's per kilowatt-hour (KWH) of electricity generated. The extent of thermal pollution is defined by the temperature of the receiving water. Effects of thermal pollution can be measured in terms of changes in aquatic life, waste assimilation capacity and dissolved oxygen of the receiving waters.

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* NOTE: 1 BTU = 0.252 kilogram-calorie = 252 gram-calories.
1 KWH = 3,413 BTU's.
Temperature Conversion °C. = 5/9 (°F. - 32).

The major waste heat-producing industries are: fossil fuel (oil, gas and coal) or nuclear power generating plants, steel mills, petroleum refineries, chemical plants, pulp and paper mills, and distilleries. Minor sources that may be important locally include: ice plants, breweries, canneries, meat-packing plants, milk-processing plants and textile mills. The significance of a waste heat load depends on the stream flow, ambient water temperature, water use and prevailing climatic conditions. The discharges of cooling and condenser waters from steam-electric generating plants, (fossil fuel or nuclear), are the major sources of thermal pollution. Stratified reservoirs may alter the natural seasonal variations in the streams below the dam, causing temperature to be below normal in spring and summer, and above normal in the fall. This paper will be confined to thermal pollution from steam-electric generating plants using fossil fuel only, except when a comparison is made between the sizes and waste heat rejected by fossil fuel and nuclear power plants.

Table 1 shows the estimated quantities of water involved in major water uses in the United States.

TABLE 1 (2)

Estimated Major Water Uses in U. S. in 1964
(in Billion Gallons)

USE	DAILY AVERAGE	ANNUAL	PERCENT OF TOTAL
Irrigation	145.48	54,195.2	40.70
Public Water Utilities	24.40	8,906.0	6.70
Rural Domestic	6.40	2,336.0	1.70
Industrial	70.80	25,842.0	19.40
Steam-Electric Utilities	114.86	41,923.9	31.50
TOTAL WATER USE	361.94	133,203.1	100.00

Steam-electric utilities are major users of water and contribute significantly greater heat loads than the other water users. The steam-electric utilities use water principally in steam generation and condenser cooling. Ninety-five percent or more of the used water is returned directly to the streams or estuaries and about 5 percent is treated in devices such as cooling towers or ponds.

SECTION II

EFFECTS OF THERMAL POLLUTION

The impact of thermal pollution on the receiving water is governed by: width, length, depth, slope and nature of flow (laminar or turbulent) of the receiving stream, dilution available, ambient water temperature, wind velocity, air temperature, humidity, and rate of evaporation. During the winter, in the northern climes, water has a greater capacity to assimilate heated discharges than in summer. The effects of heat are more localized in winter than summer due to low air and water temperatures; temperature effects may, however, be more severe in winter because of a greater change from ambient temperatures.

Increase in river water temperature, caused by any heat discharge can be approximated by the following calculations:

Let:

Q = flow of water in the stream, above the power plant intake.

Q_1 = intake of water by the power plant.

T = temperature of the stream water above the plant intake.

Q_2 = water discharged by the power plant.

T_1 = temperature of cooling water discharged from the power plant.

$(Q - Q_1)$ = flow of water in the stream, below the point of intake (assuming no natural evaporation of stream water).

T_2 = temperature of the stream water at the cross-section at the point of discharge, assuming complete and instantaneous mixing.

Then, the temperature T_2 can be approximately calculated from the following equation:

$$T_2 = \frac{(Q - Q_1)\, T + Q_2\, T_1}{(Q_1 - Q_2)} \qquad (1)$$

where: $Q_1 - Q_2$ = Water loss in the power plant operation. (2a)

$T_1 - T = \Delta T_1$ = Rise in temperature of cooling water due to heat wasted by power plants. (2b)

$T_2 - T = \Delta T_2$ = Increase in temperature of the stream water due to cooling water discharge. (2c)

Equations (2a, 2b, and 2c) may be considered as the starting point of thermal pollution studies such as, consumptive water use by power plants (Q), capacities of cooling devices needed to reduce the temperature of cooling water (T_1), methods of reducing waste heat by power plants or the effects of increase in stream water temperature (T_2) on chemical reactions and aquatic life.

As the water flows downstream from the point of discharge of cooling water, it dissipates the additional heat to the atmosphere, provided the temperature of water is higher than the temperature of the surrounding air.

The results from a temperature survey of the Monongahela River[3] show that for all temperatures of 90°F. or higher, the average rate of temperature drop was 3°F. per 1,000 feet of stream distance.

The factors that affect heat transfer from water to atmosphere are as follows:

1. Incident and reflected solar radiation.
2. Long-wave radiation from water and the atmosphere.
3. Evaporation at the water surface.
4. Heat conducted from air to water.
5. Heat advected into the water by rain and other inflows.
6. Heat transfer to or from earth.
7. Turbulence of water.
8. Wind velocity
9. Humidity.

Heat is added to receiving waters through heated effluents in addition to that normally received through solar radiation. It loses heat through evaporation, convection and radiation Heat may also be lost or gained from the river banks and bottoms; this loss or gain of heat is very small for a flowing stream and can be neglected. The above-mentioned factors are shown in Figure 1.

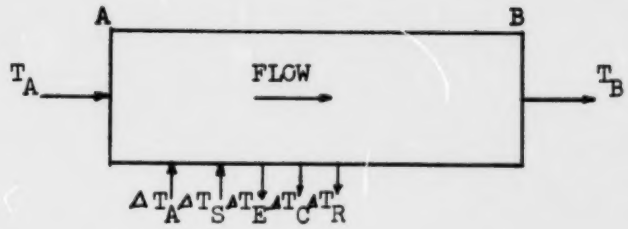

FIGURE 1
HEAT BALANCE OF A STREAM

where: AB is a Section of a stream,

T_A = temperature of water at A,

ΔT_A = temperature increase due to thermal discharge,

ΔT_S = temperature increase due to solar radiation,

ΔT_E = temperature decrease due to evaporation,

ΔT_C = temperature decrease due to convection,

ΔT_R = temperature decrease due to radiation,

T_B = temperature of water at B.

Then, assuming complete mixing, the temperature at B can be calculated from the following equation:

$$T_B = T_A + T_A + T_S - T_E - T_C - T_R \qquad (3)$$

The stream water, after receiving cooling water from a power plant, will return to its ambient temperature at some point downstream from the point of discharge, provided no further heat is added and favorable climactic conditions are present. The overall temperature of the entire downstream reach of the stream may increase if sufficient heat is added to it from various sources before the heat from any one source is completely dissipated. As the water increases in temperature its value for drinking, propagation of aquatic life, recreation, waste assimilation and industrial processes including cooling, decreases.(4)

Publication No. 3 of the Pennsylvania Department of Health(5) describes the beneficial effects of addition of heat to the source of water supply, as follows:

"From the standpoint of the municipal water operator, the addition of heat to his source of supply within the limits considered by this Committee has no detrimental effect as mentioned above. Studies have indicated that the cost of chemicals necessary to effectively coagulate and treat water can be reduced to the extent that there is a saving of 30 cents to 50 cents in treatment costs per million gallons, for each 10 degree rise in temperature. For a city which supplies many millions of gallons per day, this saving can be a sizeable amount of money.

"Higher temperatures make no difference in the operation and maintenance of the water system; but there is some objection on the part of the consumers to a supply of warm water. A few industries such as chemicals, textiles, dyeing and the photographic industry require relatively cool water. In most instances, these industries refrigerate the water which they use in their processing. In some instances, the quantities involved are quite small. To the average household consumer, cool water is desirable for drinking purposes, but most individuals refrigerate their drinking water anyway."

"A growing factor in the use of public water supplies is in connection with air-conditioning. Except for the small window-type unit, most air-conditioning installations are water-cooled. The higher the temperature of the water being used for cooling purposes, the more water is required for effective cooling."

EFFECTS OF TEMPERATURE ON CHEMICAL REACTIONS

Rates of chemical reactions[(a)] depend on the reacting substances, temperature and the concentrations of reactants. An increase in temperature increases reaction velocity and rate constant[(b)]; in general the rate of reaction increases twofold for every 10° C. (18° F.) rise in temperature. This increase in reaction rate is observed for both gaseous and liquid phase reactions.

The variation of rate constant with temperature is expressed by Van't Hoff-Arrhenious Law, represented by the following equation:

(a) Rate of a chemical reaction is defined as the rate at which the concentrations of reacting substances vary with time.

(b) According to Law of Mass Action, at any instant, the rate of any reaction is proportional to the concentrations of the reactants, i.e. $-\frac{dc}{dt} \times c$ or $\frac{dc}{dt} = kc$ where c = concentration of reactants; t = time; k = rate constant

$$\frac{d(\ln k)}{dT} = \frac{E}{RT^2} \quad \text{(Ref. 39)} \tag{4}$$

where:

k = reaction rate constant

T = absolute temperature

R = gas constant

E = energy of activation

Equation (4) can be extended to express the variations of deoxygenation and reoxygenation constants with temperature, as follows:

For deoxygenation constant:

$$\frac{k_1^{\,1}}{k_1} = \theta_1^{(T_1-T_2)} \quad \text{(Ref. 41)} \tag{5}$$

where:

$k_1^{\,1}$ = deoxygenation constant at temperature T_1

k_1 = deoxygenation constant at temperature T_2

θ_1 = temperature coefficient
= 1.047 (generally used value)

For reoxygenation constant:

$$\frac{k_2^{\,1}}{k_2} = \theta_2^{(T_1-T_2)} \quad \text{(Ref. 41)} \tag{6}$$

where:

$k_2^{\,1}$ = deoxygenation constant at temperature T_1

k_2 = deoxygenation constant at temperature T_2

θ_2 = temperature coefficient = 1.0241 (generally used value).

Variation of BOD with temperature can be expressed as:

$$\frac{L_1}{L_2} = 1 + C_L\ (T_1 - T_2) \quad \text{(Ref. 41)} \qquad (7)$$

where:

L_1 = BOD at temperature T_1

L_2 = BOD at temperature T_2

C_L = temperature characteristic

= 0.02 per degree C (Ref. 41)

Gotaas[59] pointed out that the variation of ultimate BOD with temperature is less than 2 percent, which is negligible. As a result, the ultimate BOD is assumed to be unaffected by variations in temperature.

EFFECTS OF TEMPERATURE VARIATIONS ON SOLUBILITY OF GASES

At any temperature, solubility of a gas in a liquid is proportional to the partial pressure of the gas above the liquid at equilibrium. This principle is known as Henry's Law and can be expressed mathematically as

$$C = KP \quad \text{(Ref. 39)} \qquad (8)$$

where:

C = concentration of the gas in solution

P = pressure of the gas above the solution at equilibrium

K = Henry's Law constant; and depends on the nature of the gas and liquid, the temperature and the units of C and P.

NOTE: See Appendix VI for derivations of Equations (5), (6), (7).

Equation (8) is applicable to the case where several gases are being dissolved in the same liquid at the same time, provided C represents the concentration and P the partial pressure of each gas; the constant K being different for each gas.

In general, the solubility of most gases decreases as the temperature increases. Table 2 (Ref. 39) shows the solubility coefficients(a) of various gases in water for different temperatures.

TABLE 2 (Ref. 39)

Solubility Coefficients of Gases in Water at Various Temperatures

GAS	0° C.	10° C.	25° C.	50° C.	100° C.
CO_2	1.713	1.194	0.759	0.436	-
H_2	0.02148	0.01955	0.01754	0.01608	0.0160
N_2	0.02354	0.01861	0.01434	0.01088	0.0095
O_2	0.04758	0.03802	0.02831	0.02090	0.0170

The concepts of temperature dependence of the rates of chemical reactions and the solubility of gases in water are very important in understanding the effect of temperature variation on the organic waste assimilation capacity of the stream. **Temperature exerts a triple** role: (24) affecting the rate of oxygen depletion, the saturation

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(a) Solubility coefficient of a gas is defined as the number of cubic centimeters of gas, reduced to standard conditions, which dissolve in 1 cc. of the solvent at a particular temperature and under pressure of 1 atmosphere.

capacity of oxygen in water and the rate of reaeration. As the water temperature increases, the aerobic rate of satisfaction of organic BOD increases, resulting in more rapid demands on the dissolved oxygen of the water. The normal rate ($k_1 = 0.1$) of BOD satisfaction in rivers at 68° F. (20° C.) is 20.6 percent per day of what remains each succeeding day. This rate can increase to about 40 percent per day at a temperature of 104° F. (40° C.). [24] Similar percentages can be found for other k_1 values.

As the temperature rises, the saturation level of dissolved oxygen in water declines, for example, at standard pressure the saturation dissolved oxygen values for 32° F. (0° C.), 68° F. (20° C.), 86° F. (30° C.) and 104° F. (40° C.) temperatures are 14.6, 9.2, 7.6 and 6.6 mg/l respectively.[42] The variation of saturation of oxygen in water with temperature is expressed by the following relation:[43]

$$C_s = 14.16 - 0.3943\ T + 0.007714\ T^2 - 0.0000646\ T^3 \qquad (9)$$

where:

C_s = saturation of oxygen in water, in mg/l

T = temperature in ° C.

In summary, as the stream temperature increases, the rate of BOD satisfaction increases thereby increasing the oxygen demand on the streams. The dissolved oxygen saturation concentration decreases; and the rate of reaeration increases. In general, an increase in stream temperature reduces the waste assimilation capacity of the stream, however, each case should be carefully evaluated to determine the net effect of increase in river temperature on the water quality.

EFFECTS OF TEMPERATURE VARIATIONS ON AQUATIC LIFE[48]

Following is a summary of effects of temperature variations on aquatic life:

a. The temperature of stream water, even during the summer, usually is below the optimum (95° F.-100° F.) for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable, and the food supply is abundant. Increasing the water temperature within the growth range of the bacteria causes a more rapid die-off when the food supply is limited; as it usually is.

b. Warm water fish can survive temporarily in waters heated artificially to 93° F.; some fish populations, such as roach, perch, and carp, are reduced at these high temperatures. In cold weather, stream temperatures should be substantially below 93° F. to prevent mortalities when fish move from colder water into the heated areas. Cold water non-anadromous fish populations such as trout should not be subjected to temperatures exceeding 58° F. In cold weather stream temperatures should be below 58° F. to prevent mortalities of cold water fishes.

c. Sudden changes in temperature can be more harmful to some species of fish than continued exposure to a higher temperature.

d. Fish can adapt to higher temperatures faster than to lower temperatures.

e. The maximum temperature for a given species of fish varies with the fish's rate of heating, size, and physiological condition.

f. Fish may starve at elevated temperatures because of their inability to capture food.

g. Fish seek out a preferred temperature at which they can best survive, which is several degrees below their lethal temperature.

h. The toxic effects of certain materials on fish increase with temperature.

i. Temperature changes are most important to fish in enclosed areas of the marine environment such as, estuaries and bays as opposed to open areas. Tolerance to temperature fluctuations, however, is greater in fresh-water and estuarine forms than in open water marine species.

j. There are restricted ranges of temperature within which fish can reproduce successfully; larval development especially requires narrow ranges of temperature. A fish population may exist in an excessively heated area only by continued immigration from the outside. Fish may be absent from such areas during warm summer months and present in cold winter months.

k. Increased temperatures may block the migrations of anadromous fish.

l. Cold is as significant to fish populations as heat because of the inability of fish to acclimate quickly to rapid decreases in temperature. Thus, in some areas fish populations may be limited by decreases as well as increases in temperature. The growth rate of fishes is reduced in waters colder than the optimum temperature range for the species.

m. When water temperatures increase, the predominate algal species change from diatom to green algae and finally at high temperatures to blue-green algae.

n. The number and distribution of bottom organisms decrease as water temperatures increase above 90° F., which is close to the tolerance limit for a "balanced" population. The adult stage of many species is able to tolerate higher temperatures than the eggs or young.

o. A benefit of heated effluents is the defouling of intake pipes accomplished by reversing the flow of water through the pipes.

p. Certain benefits, including open water winter fishing in otherwise ice covered areas, and a cold water fisheries downstream from deep reservoirs, can be derived from artificially induced temperature changes. The benefits to fishermen of fish being attracted to heated water in the winter months may be negligible compared to fish mortalities that may result when the fish return to the cooler water; lethal temperatures may result from heated discharges in the summer months.

SECTION III

TRENDS IN POWER GENERATION

A steam-electric generating plant consists of a heat source, fossil, or nuclear fuel, a boiler[a] where water is heated to produce steam under pressure, a turbine driven by the steam, and a condenser to cool the stream and convert it to water. Some of the steam-electric plants have an additional component for further water cooling when it leaves the condensers.

Table 3[6] shows the percentages of total kilowatt-hours of electricity generated in the United States from various types of fuel and from water.

(a) excepting boiling water reactors.

TABLE 3[6]

Methods of Electric Utility Generation in the U. S.
Percentages of Total KWH, 1930-1963

	1930	1940	1950	1960	1963
Coal	56	54	47	54	54
Natural Gas	7	8	14	21	21
Oil	3	4	10	6	6
Water Power	34	34	29	19	19
Nuclear	0	0	0	0	0.1
	100	100	100	100	100

In 1960 and 1963, coal, natural gas and oil were used as fuels for 81 percent of the total electricity produced in the United States. The proportion of hydroelectric power generation varies from one area to another; for example, 93 percent of the total capacity in the Pacific Northwest was hydroelectric while only 1 percent was produced from water in the eastern coal fields. Technological advances in steam power generation have resulted in increased plant size and in reduced fuel requirements to generate a kilowatt-hour of electricity. Figure 2[8] and Table 4[7] illustrate the decline in net heat rates for plants using fossil fuels, resulting from technological improvements during the past several years.

FIGURE 2[8]

NET HEAT RATES

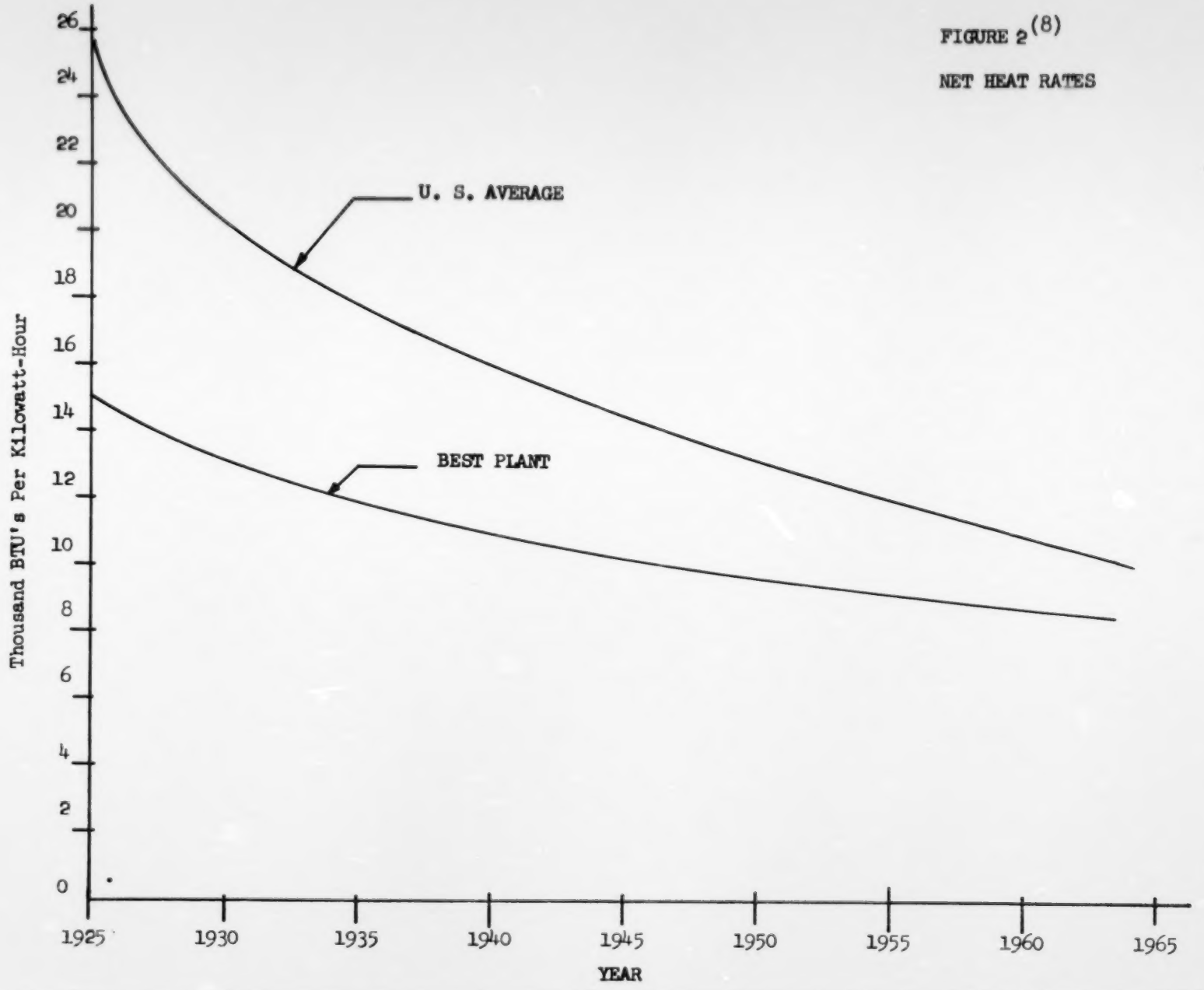


TABLE 4[7]

Net Heat Rates for Steam-Electric Generating Plants

YEAR	BEST PLANT[a] BTU/KWH	U.S.[b] AVERAGE BTU/KWH
1925	15,000	25,000
1930	12,900	19,800
1935	12,300	17,850
1940	10,729	16,400
1945	10,345	15,800
1950	9,378	14,030
1955	9,151	11,699
1960	8,975	10,760
1961	8,760	10,650
1962	8,588	10,558

(a) Plants in service full year.

(b) Exclusive of Alaska and Hawaii.

Net heat rate is the quantity of heat required to produce a kilowatt-hour of electricity and is a measure of thermal efficiency of a plant. As the net heat rate decreases, the thermal efficiency increases. The fuel requirements for generating 1 kilowatt-hour of electricity (net heat rate) have decreased with the increases in unit sizes, temperatures and pressures, and improvements in equipment design. For example, the average National net heat rate in 1925 was

25,000 BTU's/kilowatt-hour, in 1965 was 10,500 BTU's/kilowatt-hour. The estimated heat rate for 1980 is 8,900 BTU's/kilowatt-hour.

In the United States, Nuclear power plants can be divided into three major caregories: Boiling Water Reactors, Pressurized Water Reactors and Gas Cooled Reactors. Tables 5(a), (b) and (c)[9] show the Nuclear power plants, start-up years and the design net heat rates. It will be observed from these tables that the net heat rates have tended to decline with the improvements in technology coupled with increases in plant size.

TABLE 5[9]

Net Heat Rates For Nuclear Power Plants

(a) Boiling Water Reactors

REACTOR	ELECTRICAL POWER, MWE*	START-UP YEAR	DESIGN NET HEAT RATE BTU/KWH
Dresden No. 1	200	1960	11,946
Big Rock Point	71	1963	11,536
Humboldt Bay	68	1963	12,044
La Crosse	52	1966	10,829
Oyster Creek	515	1967	10,601
Nine Mile Point	500	1967	10,498
Dresden No. 2	715	1969	10,761
Millstone	549	1969	10,734
Dresden No. 3	715	1970	10,761

*MWE-Megawatts Electrical

TABLE 5[9]

Net Heat Rates For Nuclear Power Plants

(a) Boiling Water Reactors
(Continued)

REACTOR	ELECTRICAL POWER, MWE*	START-UP YEAR	DESIGN NET HEAT RATE BTU/KWH
Monticello	472	1970	10,621
Quad-Cities No. 1	715	1970	10,761
Vermont Yankee	537	1970	10,167
Browns Ferry No. 1	1,098	1971	10,236
Browns Ferry No. 2	1,098	1971	10,236
Quad-Cities No. 2	715	1971	10,761
Pilgrim	655	1971	9,962
(b) Pressurized Water Reactors			
Yankee	175	1960	11,699
San Onofre	429	1966	10,713
Connecticut Yankee	490	1967	10,007
Indian Point No. 2	873	1969	10,782
Ginna	420	1969	10,563
H. B. Robinson	700	1970	10,212
Malibu	462	1970	10,881
Palisades	710	1970	10,631
Point Beach	454	1970	10,484
Turkey Point No. 3	690	1970	10,881
Oconee No. 1	839	1971	9,973

*MWE-Megawatts Electrical

TABLE 5[9]

Net Heat Rates For Nuclear Power Plants

(b) Pressurized Water Reactors
(Continued)

REACTOR	ELECTRICAL POWER, MWE*	START-UP YEAR	DESIGN NET HEAT RATE BTU/KWH
Turkey Point No. 4	690	1971	10,881
Burlington	1,035	1971	10,164
Fort Calhoun	481	1971	10,075
Surry No. 1	848	1971	10,246
Three Mile Island	871	1971	9,932
Oconee No. 2	839	1972	9,973
Diablo Canyon	1,090	1972	10,174
Surry No. 2	848	1972	10,246
(c) Gas Cooled Reactors			
Peach Bottom	40	1966	9,812
Fort St. Vram	330	1971	8,614

The total use of electricity in the United States has increased steadily throughout the history of power industry. The total use of electricity in 1902, including public and industrial power, was about 6 billion kilowatt-hours[10] and in 1960 was about 841.6 billion kilowatt-hours.[10] The estimated quantities for

*MWE-Megawatt Electrical

1970 and 1980 are 1,600 [11] and 1,800[11] billion kilowatt-hours. The trend of steam-electric generation exceeds the upward trend of total power generation, as shown in Table 6[12].

TABLE 6[12]

Trend of Steam-Electric Generation

YEAR	TOTAL ELECTRIC UTILITY INDUSTRY[a] KWH IN BILLIONS	STEAM-ELECTRIC GENERATED[a] KWH IN BILLIONS
1902	2.5	-
1912	11.6	7.1[b]
1920	39.4	23.5
1930	91.1	59.3
1940	141.8	93.0
1950	329.1	229.5
1960	753.4	603.3

(a) Not including industrial plants contributing to public supply.

(b) Includes internal combustion.

The total power generated by the electric utilities, excluding power generation by the industrial plants, increased about 65 times during a period of 48 years, while steam-electric generation increased about 85 times during the same period.

Fuel Used in Steam-Electric Generation

The fuel used in steam-electric generation is either fossil or nuclear. Fossil fuel used in power generation generally is either coal, fuel oil or natural gas, or a combination of these. The increase in fuel consumption with the increase in steam-electric generation, is shown in Table 7[13].

TABLE 7[13]

Use of Fuel for Electric Generation[a]

YEAR	COAL (Thousands of Short Tons)	FUEL OIL (Thousands 42-Gal.bbls.)	GAS (M cu.ft.)
1925	35,615	9,794	45,472
1930	40,278	8,805	119,553
1935	32,715	11,257	124,118
1940	51,474	16,325	180,096
1945	74,725	20,228	326,212
1950	91,871	75,420	628,919
1955	143,759	75,274	1,153,280
1960	176,634	85,340	1,724,762
Approx. BTU for 1960	$4.25X10^{15}$	$0.54X10^{15}$	$1.78X10^{15}$

(a) Excluding Alaska and Hawaii

Over a period of 35 years, the use of coal has increased about five times, fuel oil about nine times and gas about 38 times.

The total fuel (fossil and nuclear) requirements, in terms of BTU, in 1960 was 6,540 trillion BTU's. The estimated fuel requirements for 1970 and 1980 are 12,163 and 21,707 trillion BTU's respectively or an increase of 86 percent and 231.9 percent respectively over the requirements for 1960.(38)

The cost of power production has not changed materially during the post-war years, even though the construction costs and wages have increased substantially. This is due to decreasing net heat rates (BTU/KWH) and improvements in coal mining, and oil and gas production methods. The prices and average BTU available from coal, oil and gas are shown in Table 8 (14).

TABLE 8(14)

Analysis of Fuel for Electric Generation - Total Electric Utility
(Excluding Alaska and Hawaii)

	1948	1950	1955	1960
		COAL		
Avg. Cost per Ton	$6.69	$6.38	$6.01	$6.26
Avg. BTU per lb.	11,980	11,839	12,048	12,041
Cost per M BTU	$0.2792	$0.2694	$0.2494	$0.2599
		OIL		
Avg. Cost per bbl.	$2.81	$2.00	$2.12	$2.17
Avg. BTU per gal.	147,653	149,699	150,526	150,514
Cost per M BTU	$0.4531	$0.3181	$0.3353	$0.3433
		GAS		
Avg. Cost per 1000 cu. ft.	$0.11	$0.118	$0.188	$0.252
Avg. BTU per cu.ft.	1,053	960	1,006	1,034
Cost per M BTU	$0.104	$0.122	$0.186	$0.243

Based on the available data, the cost of coal and oil have decreased slightly while the cost of gas has more than doubled from 1948 to 1960 (Table 8)[14]. The increase in gas prices has not significantly affected the total fuel cost per kilowatt-hour produced, as shown in Table 9[15].

TABLE 9[15]

Fuel Expenses in Power Production
(Mills per KWH)

YEAR	1957	1958	1959	1960	1961	1962
Fuel Cost	3.02	2.94	2.82	2.81	2.78	2.75

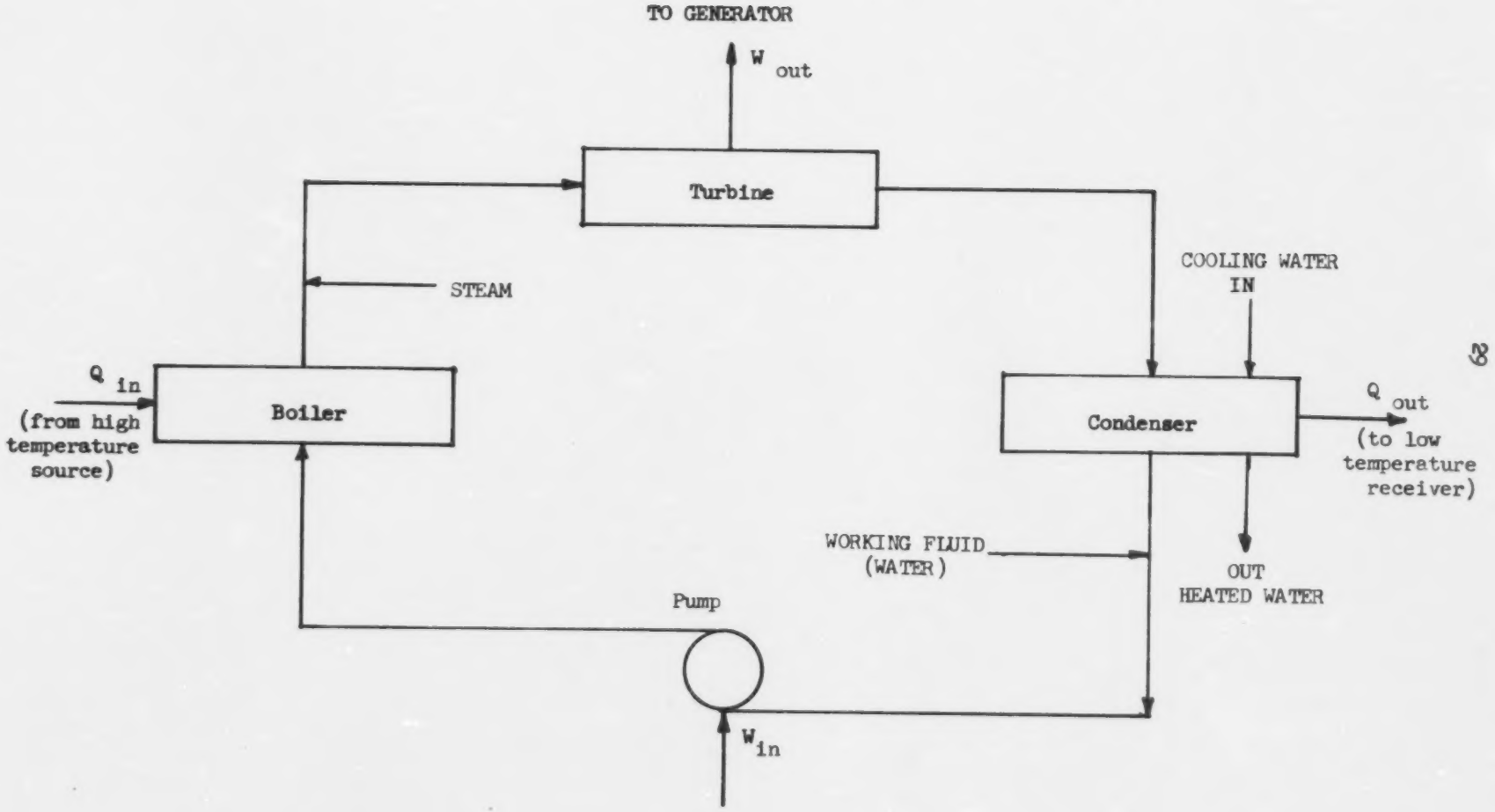
SECTION IV

POWER GENERATION

Apparatus required for steam-electric generation includes the: pump, boiler, turbine or reciprocating engine, condenser and water, (Figure 3[16]). In power plant operation water flows from the condenser at low pressure and temperature, to the pump, which delivers it to the boiler. In the boiler, it is converted to steam by heat received from either fossil or nuclear fuel. Steam, at high pressure and temperature, then flows through the turbine or turbo-generator, where electricity is generated. The steam, exhausted by the turbine, is at lower pressure and temperature because of the work done by it in driving the turbine. This steam, then, passes to the condenser where it is converted to water by transferring heat to the cooling water. The cycle, completed by water as described above, is called a "Power Cycle." Engines, operating on a power cycle, are called "Heat Engines."

FIGURE 3

FLOW-DIAGRAM FOR A
POWER PLANT



Heat is coverted to mechanical work in heat engines and the extent of conversion is denoted as the "Thermal Efficiency" of the heat engine. Thermal efficiency is defined as the amount of heat used to do mechanical work divided by the total amount of heat supplied to the engine. If,

E = thermal efficiency, in percent

Q_1 = total amount of heat supplied to the engine, in BTU or heat units

Q_2 = amount of heat rejected to cooling water, in BTU or heat units,

then, neglecting other heat losses, the thermal efficiency can be expressed as

$$E = \frac{Q_1 - Q_2}{Q_1} = \frac{\text{Amount of heat used to do work}}{\text{Total amount of heat supplied to the engine}} \qquad (10)$$

HEAT CYCLES:

Heat cycles generally associated with steam-electric generation using fossil fuels are: (i) Carnot Cycle and (ii) Rankine Cycle. The Carnot Cycle is an ideal or theoretical cycle and the Rankine Cycle is the practical cycle and is commonly used in power generation. Following is a brief description of the two cycles:

(i) Carnot Cycle:

In a Carnot Cycle, the temperature and pressure of the working fluid, at temperature T_1, are increased by a reversible[(a)] adiabatic[(b)] process. When the temperature of the fluid reaches T_2, it is exposed

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(a) Reversible Process - If the process that a system has undergone is reversed, and if the system and surroundings revert to their initial state, then the process is called a "Reversible Process."

(b) Adiabatic Process[(44)] - If heat is neither supplied to nor removed from a system during a process, then the system undergoes an Adiabatic Process. The processes of interest are adiabatic compression and expansion.

to the external source of heat and is allowed to expand isothermally[c]. The fluid is allowed to do mechanical work during this expansion. Then the source of heat is removed and the fluid is allowed to expand further adiabatically, losing temperature and pressure, until its temperature drops to T_1. At this point the fluid starts rejecting heat isothermally to the surroundings or the cooling waters. After all the excess heat is rejected the fluid is ready to start the next cycle. The thermal efficiency of the Carnot Cycle is:

$$E \text{ (in percent)} = \frac{T_2 - T_1}{T_2} \times 100 \qquad (11)$$

Where: T_1 = initial temperature.

T_2 = final temperature.

(T_1 and T_2 are measured on absolute scale)

The thermal efficiency increases as the final temperature T_2 increases, or as the initial temperature T_1 decreases (Equation 11). The theoretical maximum efficiency of 100 percent could be achieved if the temperature T_1 were zero on the absolute scale. Obviously, this is not feasible since the lower temperature, T_1, is limited by the temperature of the surrounding air or water, to which the heat from the fluid is rejected, which is substantially higher than the absolute zero. The upper temperature limit, T_2, is governed by the capabilities of the metals to withstand high pressures and temperatures for sustained periods of time. The highest temperature used in steam cycles in 1964 was 1200°F. (634.7°C.)[1] or 1660° on the Rankine Scale. If the average

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(c) Isothermal Process - Any process in which the temperature of the system remains constant is called an "Isothermal Process." The processes of interest are isothermal expansion and compression.

annual temperature of air or water is assumed to be 60°F. (15.6 C.) or 520° on the Rankine Scale, then, the theoretical efficiency of the Carnot Cycle is:

$$E = \frac{1660 - 520}{1660} \times 100 \qquad (12)$$

$$= 68.7\%$$

(ii) Rankine Cycle:

In the Rankine Cycle, the working fluid is water. Condensate pumps increase the pressure of the condenser water to boiler pressure by a reversible adiabatic process. In the boiler, the water is first heated at constant pressure to the saturation temperature, corresponding to the boiler pressure, and is then vaporized. The steam leaving the boiler is allowed to expand in the turbine, in a reversible adiabatic process to the condenser pressure. In the condenser, the mixture of steam and water is condensed, isothermally, to water and the cycle is ready to start again. The thermal efficiency of the Rankine Cycle is expressed as:

$$E \text{ (in percent)} = \frac{Q_{IN} - Q_{OUT}}{Q_{IN}} \times 100 \qquad (13)$$

Where: Q_{IN} = Total amount of heat supplied to the cycle.

Q_{OUT} = Heat rejected in the condenser to cooling water.

The maximum thermal efficiency so far attained in a steam cycle is around 42 percent, which is less than the theoretical thermal efficiency of Carnot Cycle (68.4 percent) and much less than 100 percent.

The reason for the difference in thermal efficiencies of the two cycles is that in the Carnot Cycle, all the heat is applied to the working fluid at the highest temperature whereas, in the Rankine Cycle some heat is applied to water at lower temperatures to bring the temperature of the water to saturation temperature corresponding to the boiler pressure.

METHODS OF IMPROVING THE EFFICIENCIES OF STEAM CYCLES

Thermal efficiency of a steam cycle can be improved by reducing the amount of heat rejected to the cooling water. Hence, an increase in thermal efficiency results in reduction of thermal pollution. Thermal efficiencies can be increased in the following manner:

1. Use of Condensers.

A condenser, used in connection with steam engines, is a device where the steam, exhausted by the turbine, is converted to water. The steam flows into the condenser from the turbine and is cooled sufficiently so that it is converted to water, thereby creating a partial vacuum in the condenser. The effect of this partial vacuum is to increase the working pressure of the turbine, in other words, the turbine can exhaust the steam at a considerably lower pressure than can the steam engine operating without a condenser. The range of the exhaust pressure of a steam engine with a condenser is 10 to 14 pounds per square inch below the atmospheric pressure, the corresponding range for a steam engine without a condenser being 0 to 5 pounds per square inch above the atmospheric pressure[45].

The decrease in exhaust pressure increases the thermal efficiency of the steam engine, as shown by the following example:(46)

Consider a steam engine using saturated steam at 115 psi (absolute). According to the steam tables, the temperature of steam at this pressure is 338° F. or 798° Rankine (absolute). The pressure of the exhaust steam is, for example, 16 psi (absolute) when the steam engine does not have a condenser and is 2 psi (absolute), for example, when the steam engine has a condenser. The temperatures of steam, corresponding to these exhaust pressures, are 676° Rankine and 586° Rankine respectively.

$$E = \frac{T_2 - T_1}{T_2} \times 100 \text{ (Same as Equation (11))} \qquad (14)$$

Hence, for a steam engine without a condenser:

$$E = \frac{798 - 676}{798} \times 100 = 15.3\%$$

and, for steam engine with condenser:

$$E = \frac{798 - 586}{798} = 26.6\%$$

From the above example, it is apparent that the thermal efficiency increases substantially when condensers are used.

2. Feedwater Heating.

Feedwater heating is a process where boiler feedwater is heated before admitting it into the boiler. Steam is allowed to expand in the turbine by a reversible adiabatic process, but some of the steam is bled-off from the turbine at one or more sections between the inlet and outlet ends. This steam is condensed outside the turbine at constant pressure. The heat given up by the steam is used to heat the boiler feedwater.

The net heat rate of the best plant in 1962 was 8,588 BTU/KWH (Table 3), which means that 8,588 BTU's of heat were supplied to the plant to generate 1 KWH of electricity. About 40 percent (3,413 BTU's), used to produce 1 KWH of electricity and about 60 percent (5,175 BTU's), was wasted to the environment.

Of the 60 percent, 42.5 percent of the heat is discarded to the cooling water and the other 17.5 percent constitutes various other heat losses, as shown in Figure 4. In the feedwater heating, the heat of the steam, exhausted by the turbine, is used to heat the feedwater from its ambient temperature to about 212° F. (100° C.)

The entropy diagram for the Rankine Cycle is shown in Figure 19 It is the practical steam cycle where heat from an external source is added to the water over a wide range of temperatures. The feedwater heating raises the average temperature of heat addition, and reduces the heat rejection up to 37 percent, depending on the number of heaters used.(58)

The flow diagram and the entropy diagram for feedwater heaters are shown in Appendix V.

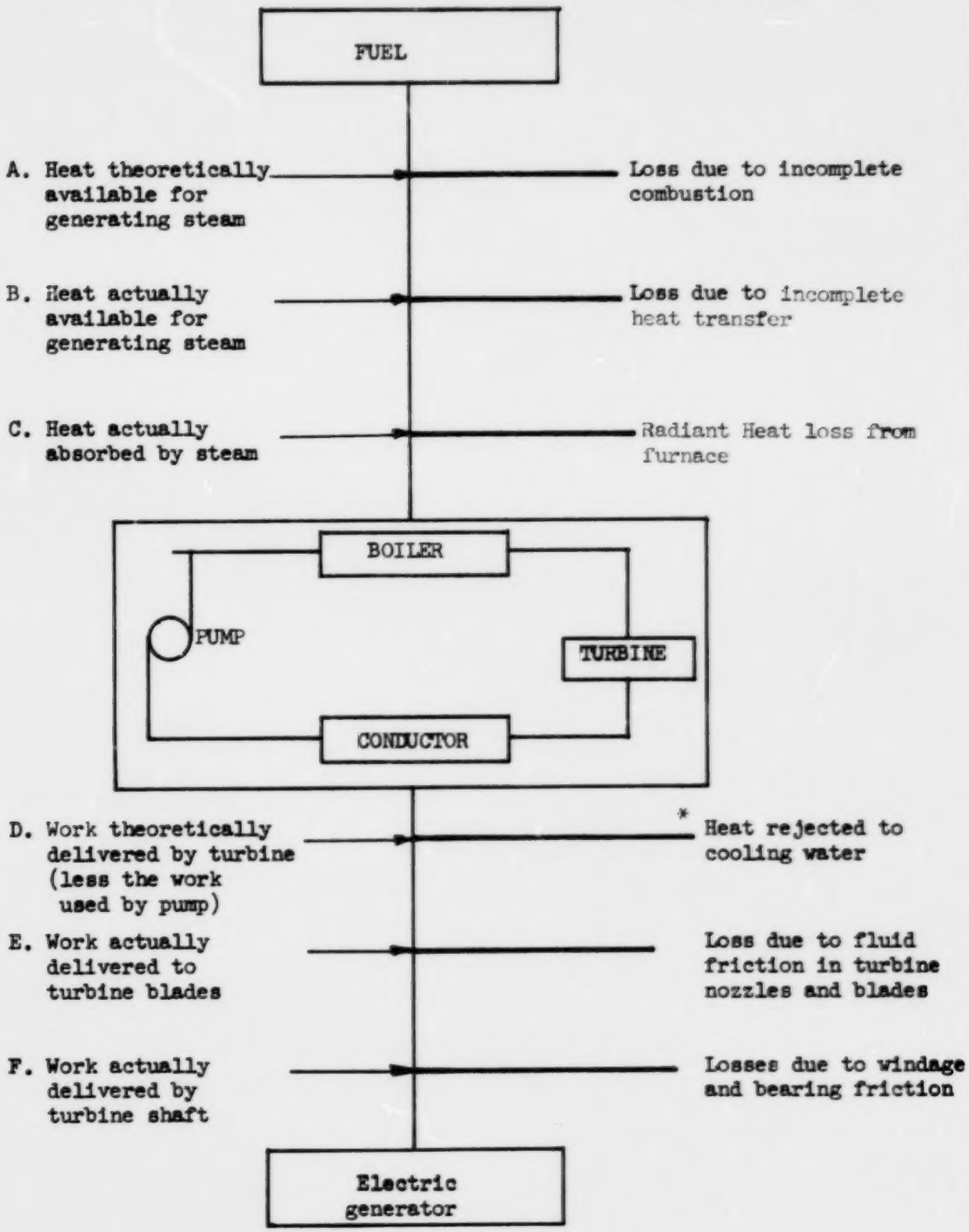
3. Superheating.

In a Rankine Cycle, steam obtained from the boiler is at saturation temperature(a) corresponding to the boiler pressure. If the temperature of steam is increased beyond the saturation temperature, then the steam is called "Superheated Steam". In the superheating process, saturated steam from the boiler is heated by hot furnace gases, at constant pressure in a superheater, which consists of banks of tubes.

(a) Saturation Temperature - Saturation temperature is defined as the temperature at which a fluid changes from liquid phase to vapor phase when heated at constant pressure. Hence for any pressure there is only one saturation temperature.

FIGURE 4

IMPORTANT LOSSES IN A STEAM POWER PLANT


FUEL
A. Heat theoretically available for generating steam
Loss due to incomplete combustion
B. Heat actually available for generating steam
Loss due to incomplete heat transfer
C. Heat actually absorbed by steam
Radiant Heat loss from furnace
BOILER
PUMP
TURBINE
CONDUCTOR
D. Work theoretically delivered by turbine (less the work used by pump)
* Heat rejected to cooling water
E. Work actually delivered to turbine blades
Loss due to fluid friction in turbine nozzles and blades
F. Work actually delivered by turbine shaft
Losses due to windage and bearing friction
Electric generator

NOTE: Total losses approximate 60% of fuel supply.

* Approximately 43% of total loss (26% of total fuel value) rejected to cooling water.

The advantage of the superheating process is that for a given pressure, there is no limit to which the temperature can be increased other than the capability of the metals to withstand high temperatures and pressures. Thus, superheated steam provides operating temperatures higher than those for saturated steam. Hence, the efficiency of a steam engine using superheating steam is higher than that of one using the basic Rankine Cycle, because the heat rejected is reduced by about 1.4 percent for each 50° F. increase in steam temperature by superheaters(58). The added cost involved in superheating steam is less than the value of the gain in efficiency; consequently, most power plants use superheaters.

The entropy diagram for superheating is given in Appendix V.

4. Reheating.

In the reheating process, steam, initially superheated, is introduced into a high pressure turbine and is allowed to expand to a pressure at which condensation of steam just starts. At this point, the steam is exhausted from the turbine and superheated at constant pressure in a reheater to the initial temperature. This superheated steam is introduced in a low pressure turbine, or the low pressure end of the high pressure turbine, and is allowed to expand to the condenser pressure. The reheating process increases the average temperature of heat addition and increases the thermal efficiency of the cycle, because the heat rejected is decreased by about 1.4 percent for each 50° F. increase in steam temperature by reheaters(58).

SECTION V

QUANTITIES OF HEAT WASTED

HEAT LOSSES

The major heat losses in a power plant can be divided into two categories: (1) heat loss in the furnace and (2) heat rejected to the cooling water, Figure 14.[17]

(1) The heat loss in the furnace can be subdivided into the following categories:

(a) Incomplete combustion, may be due to insufficient supply of air or improper mixing of air and fuel, or presence of moisture in the fuel.

(b) Incomplete heat transfer, may be due to heat retained by inert products of combustion (ash or slag) or incomplete transfer of heat from combustion gases to water or the heat absorbed by the metal tubes containing water or the heat carried by flue gases out of the stack.

(c) Radiant heat loss from the furnace to the surroundings.

(2) The major source of thermal pollution is the heat rejected to the condenser cooling water (Item D in Figure 4). Steam, exhausted by the turbine, is at low temperature and pressure when it enters the condenser where it is converted to water. In the process, heat from steam is transferred to the circulating condenser cooling water.

ESTIMATED COOLING WATER REQUIREMENTS

Cooling water requirements were calculated for power plants, listed in "Steam-Electric Plant Construction Cost and Annual Production Expenses, Federal Power Commission, 1965," using fossil fuels for steam generation. These requirements are shown in Table 11, in Appendix II. The list does not include many plants that have been constructed since the FPC Report.

The following assumptions were made in computing cooling water requirements:

(a) Five temperature rises (10°F., 12°F., 13°F., 15°F. and 20°F.) of the cooling water were selected. Cooling water temperature rises generally encountered in power plant operations range from 10°F. to 20°F., with an average rise of 13°F.

(b) Heat losses other than those to cooling water were assumed to be 17.5 percent of the net heat rate (BTU/KWH) of the plant. These heat losses are: boiler losses - 10 percent,

generator and auxiliary losses - 2.5 percent and boilerfeed and other plant losses - 5 percent.

(c) Cooling water calculations are based on once-through cooling.

Sample calculation for cooling requirements is shown in Appendix II. Estimated cooling water requirements for various temperature rises for 514 power plants are presented in Table 11, Appendix II, and graphically represented in Figure 5.

SUMMARY OF TABLE 11

Number of Plants: 514

Total Net Electricity Generated in 1965: 812 - 8×10^9 KWH

Total Heat Discharged to Cooling Water in 1965: $4,235 \times 10^{12}$ BTU

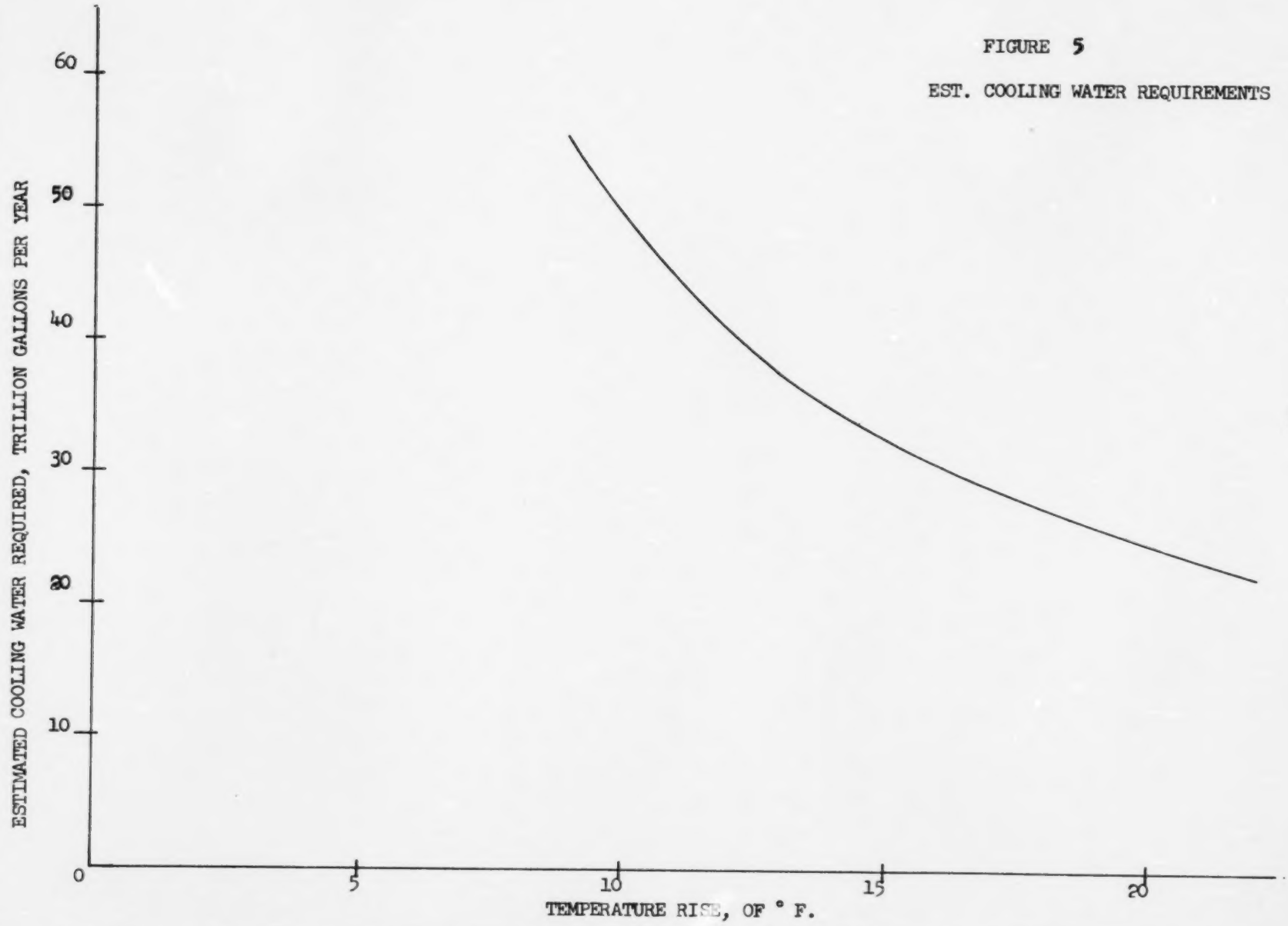
Estimated Cooling Water Requirements for selected rises in temperature of cooling water:

Temperature Rise	Cooling Water Requirements Trillion Gals./Yr.	cfs
10°F.	49.2	207,000
12°F.	41.0	
13°F.	37.4	
15°F.	32.8	
20°F.	24.7	108,000

The cooling water requirement of 207,000 cfs for a 10°F. rise in temperature is greater than the combined minimum daily flow of record of two of the largest rivers in the United States, the Mississippi River at Vicksburg, Mississippi, and the Niagara River at Buffalo, New York. Even the minimum estimated requirement of 108,000 cfs for a

FIGURE 5

EST. COOLING WATER REQUIREMENTS



20°F. rise is greater than the minimum daily flow of the Mississippi River at Vicksburg or the Niagara River at Buffalo.

The nuclear power plants in operation at present have lower efficiencies than the fossil fuel power plants. As a result nuclear plants reject more heat than that rejected by fossil fuel plants, thereby increasing the cooling water requirements. Davidson and Bradshaw[60] state that for a modern coal-fired power plant, approximately 6,000 BTU's per KWH must be dissipated by means of cooling water as compared to approximately 10,000 BTU's per KWH for nuclear plants.

SECTION VI

PROCEDURES FOR CONTROLLING THERMAL POLLUTION

The major source of thermal pollution from a steam-electric generating plant is the waste heat discharged from the steam, exhausted by the turbine or turbogenerator, to the cooling water in the condenser. Thermal pollution can be reduced by improving thermal efficiencies of power plants, by evaporative or non-evaporative cooling, or by generating electricity by methods that do not use steam cycles. Improvement of thermal efficiencies, as a method of thermal pollution control, is limited by the condenser pressure and the ambient temperature of the cooling water, but results in some reduction of thermal pollution. Evaporative cooling is the most common method of reducing thermal pollution at the present time.

EVAPORATIVE COOLING

Heated water from the condenser loses its heat to the environment through evaporation and by conduction, convection and radiation, evaporation being the major cause of heat loss. The cooling effect of evaporation is because heat, equivalent to the latent heat of vaporization, required to convert water to vapor is drawn from the

heated water itself. Every pound of water evaporated will carry away 1,000 BTU's and cool 1,000 pounds of water 1°F. or 100 pounds of water 10°F. A minor portion of heat, required for vaporization, is abstracted from the surrounding air.

Several types of cooling devices are described below. These devices operate on the principle of intimate contact between air and heated water and the evaporation of water.

Cooling Ponds

A Cooling Pond consists of an impoundment, to receive heated water from the condenser, and an inlet device and outlet pipe. The inlet device consists of a shallow and wide trough to provide large surface area for heat transfer. The inlet trough and outlet pipe are located at the opposite ends of the pond to prevent short circuiting of heated water. The main advantage of a Cooling Pond is low construction cost. The disadvantages are: low rate of heat transfer and large pond area requirement about 0.65 gallons of water per hour per square foot of the surface area when heated water is cooled 45°F.(18).

Spray Ponds

A Spray Pond consists of a reservoir with a spray system located about 6 to 8 feet above the water surface. Nozzles, used in the spray system, break the heated water into fine droplets. These droplets provide maximum of water surface to facilitate more efficient heat dissipation than the surface transfer of the Cooling Pond. In some instances, Spray Ponds have louver fences to prevent water from being blown away As a rough estimate, it may be assumed that Spray Ponds will cool 15 to 20 gallons of water per hour, per square foot

of the surface area when heated water is cooled from 110°F. or 120°F. to 70°F.[18] The advantage of a Spray Pond over the Cooling Pond is that the land area required for cooling is smaller. The main disadvantage is that the time of contact between air and sprayed water is limited, resulting in limited heat dissipation.

Natural Draft Towers

Towers of this type are also known as Atmospheric Towers. In a Natural Draft or Atmospheric Tower, the heated water is pumped to the top of the tower and is allowed to flow downward through a distribution system. Air movement through the tower is dependent on the wind velocity outside the tower. Louvers are installed along the height of the tower to provide horizontal flow of entering air.

There are two types of Natural Draft Towers: Spray Tower, Figure 6[18], where nozzles are provided at the top of the towers, to break the heated water into droplets; and wood-baffled towers, where wooden baffles are used as splash boards to increase the wetted surface that comes in contact with air.

The disadvantages of the Natural Draft Towers are that they must be placed broadside to the prevailing winds and that they have to be constructed in an open area where the surrounding structures such as, hills or large buildings, do not block off the wind. The advantages are: low maintenance cost and the air exhausted by the tower is not subject to recirculation. This type of a tower is estimated to cool 60 to 120 gallons per hour per square foot of ground area, when water is cooled from 110°F. or 120°F. to 70°F.[55]

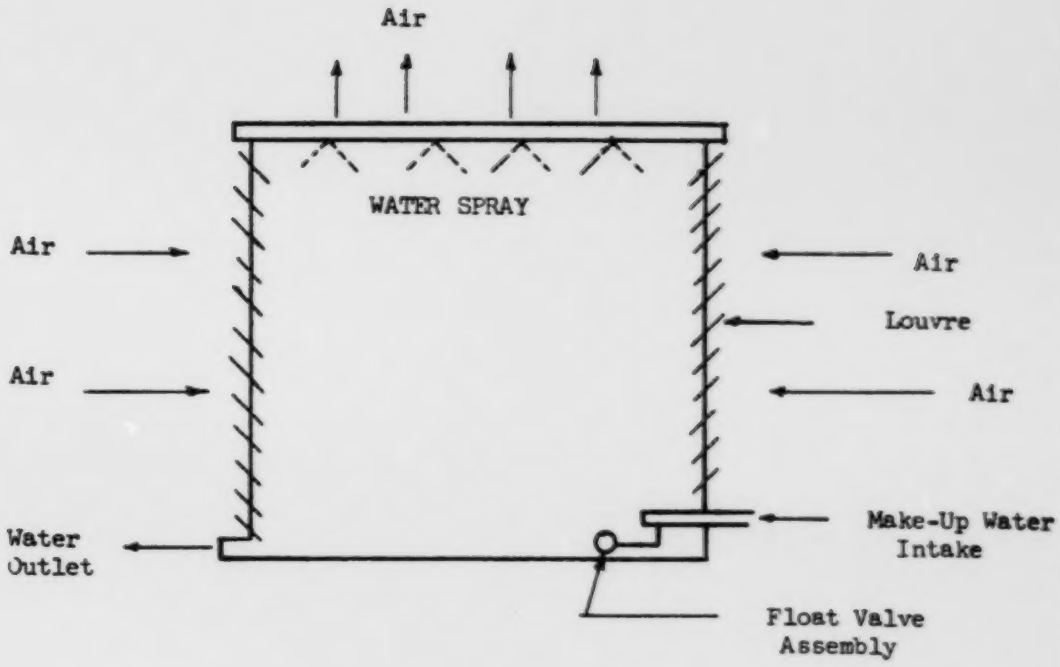


Figure 6

SPRAY TOWER

Natural Draft Chimney Tower

A Natural Draft Chimney Tower consists of packing material, used to distribute water, and a large chimney stack to induce air draft through the tower. The packing material occupies a short section, towards the bottom of the tower. The draft is a result of a number of complicated interrelated effects such as, the atmospheric air pressure differential due to height of the stack; induced air flow due to difference in wind velocities; the temperature difference of air heated by water; and an increase in volatility due to vaporization.

The advantages of this type of a tower are the low maintenance cost, independent of atmospheric wind since air draft is induced through the tower, and air and water flows, countercurrent to one another, result in high cooling efficiency. This type of tower is estimated to cool 360 gallons per hour per square foot of ground area if the heated water is cooled from 110°F. or 120°F. to 70°F.(55)

The disadvantages of the tower are: resistance to air flow must be kept at a minimum; great chimney heights are necessary to induce flow of air; and inlet hot water temperature must be higher than the air dry bulb temperature.

Mechanical Draft Towers

A Mechanical Draft Tower uses fans for air movement through the tower. Fans may be located at either air intake or outlet end of the tower. This type of tower gives absolute control over the air supply and eliminates items like air resistance and wind direction or velocity encountered in other types of cooling towers.

NOTE: Definitions of terms used in Cooling Towers are given in Appendix I.

There are three types of Mechanical Draft Towers: Forced Draft Towers, Figure 7[18], where one or more fans are located at the air intake end of the tower and two types of Induced Draft Towers, where one or more fans are located at the air outlet end of the tower. The two types of Induced Draft Towers are: Counterflow Induced Draft Tower, Figure 8[18] and Crossflow Induced Draft Tower, Figure 9[18]. In a Counterflow Tower, air flows upwards and the water flows downwards whereas, in a Crossflow Tower, the air movement is horizontal and water flow is vertical.

The advantages of a Mechanical Draft Tower are: close control of cold water (tower effluent) temperature, closer approach[a] and longer range[b]. Furthermore, the location of the tower is not restricted.

The disadvantages are: high operating and maintenance cost; subject to recirculation of hot and humid air; and subject to mechanical failures.

As a rough approximation, it may be assumed that a Mechanical Draft Tower will cool about 360 gallons per hour of water per square foot of ground area, if water is cooled from 110°F. or 120°F. to 70°F.[55].

EFFICIENCY OF EVAPORATIVE COOLING DEVICES

The overall efficiency of any evaporative cooling device such as a Cooling Pond, Spray Pond or Cooling Tower can be calculated from

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(a) APPROACH - The difference in temperature between that of the cold water leaving and the wet bulb temperature of the air entering the tower.

(b) RANGE - The difference between the inlet hot water temperature and the outlet cool water temperature or the number of degrees the water is cooled in the tower.

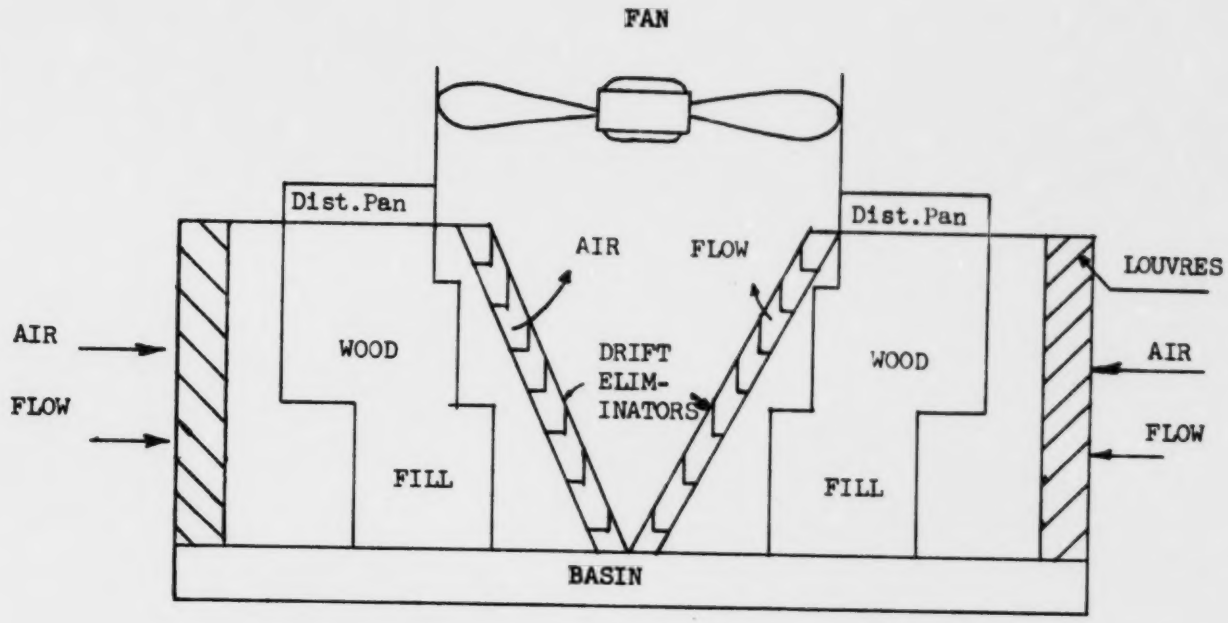

FIGURE 7

CROSS-FLOW TOWER

the following formula:[46]

$$E = \frac{(T_{IN} - T_{OUT})}{(T_{IN} - T_{W})} \times 100 \qquad (15)$$

where:

E = Efficiency, in percent.

T_{IN} = Temperature, in degrees F., of heated water coming into the cooling device.

T_{OUT} = Temperature, in degrees F., of cooled water leaving the device.

T_{W} = Wet-bulb temperature, in degrees F., of the surrounding atmosphere.

Wet-bulb temperature of the air is used as a measure of the efficiency because it is the lowest temperature to which heated water can be cooled by evaporative cooling. The reason for this is apparent from the definition of wet-bulb temperature, as the dynamic equilibrium temperature attained by a water surface when exposed to air in a manner such that the sensible heat transferred from the air to the water is equal to the latent heat carried away by evaporation of water vapor into the gas.[56]

Following is a summary of the approximate evaporative capacities of the various cooling devices discussed above:

Cooling Device	Approximate Cooling Capacity
1. Cooling Ponds	0.65 gallons of water/hour/sq. ft. of surface area when water is cooled through 45°F.
2. Spray Ponds	20 gallons of water/hour/sq. ft. of surface area when water is cooled 40°F. to 50°F.

Cooling Device		Approximate Cooling Capacity
3.	Natural Draft Towers	60 - 120 gallons of water/hour/sq. ft. of ground area when water is cooled 40°F. to 50°F.
4.	Natural Draft Chimney Towers	360 gallons of water/hour/sq. ft. of ground area when water is cooled 40°F. to 50°F.
5.	Mechanical Draft Towers	360 gallons of water/hour/sq. ft. of ground area when water is cooled 40°F. to 50°F.

Consumptive Use of Water

Water consumption or losses, in the operation of evaporative devices, can be divided in two categories: evaporation of water and windage loss. Evaporation of water, resulting in cooling the heated water, is the major consumptive use. It has been pointed out earlier in this section that approximately 1,000 BTU's are required to evaporate 1 pound of water, which is the amount of heat lost in cooling 100 pounds of water 10°F.(56) Therefore, for each 10°F. of cooling effected, approximately 1 percent of water is lost by evaporation. For example, if condenser water at 105°F. is cooled to 80°F. in an evaporative cooling device, then the loss of water due to evaporation is 2.5 percent. Windage losses are very small as compared to evaporation losses, being approximately 0.2 percent for a well-designed Mechanical or Natural Draft Cooling Tower(56). The windage loss for Spray Ponds is slightly higher.

Table 10(57) gives an estimate of average water requirements for a temperature rise of 15°F. in condensers and consumptive water use for steam-electric generating plants, using fossil fuels, during the period 1965-2020.

On the basis of the steam-power plants estimated total cooling water requirements of 140,000 cfs for 15°F. rise in temperature, the total water consumption or loss in cooling would total about 380 cfs. This is equivalent to the minimum daily flow of record for the Mississippi River at Prescott, Wisconsin.

TABLE 10(57)

WATER REQUIREMENTS AND CONSUMPTIVE WATER USE

YEAR	Avg. Water Requirement for 15°F. Rise (Gals./KWH)	AVERAGE CONSUMPTIVE USE OF WATER (in Gallons/KWH)		
		Once-through	Cooling Ponds	Cooling Towers
1965	40	0.3	0.4	0.5
1980	35	0.2	0.3	0.4
2000	30	0.15	0.25	0.35
2020	25	0.1	0.2	0.3

NOTE: "Once-through" means that the water was withdrawn from its source, such as river or lake, or ocean, passed through the condenser and returned to the source.

NON-EVAPORATIVE COOLING

The air-cooled heat exchanger is an example of a non-evaporative cooling device. An air-cooled heat exchanger works on the same principle as a household heater using hot water or steam. The heater consists of a tube with fins spaced at regular intervals along the length of the tubes, through which the hot water or steam flows. Air flows through the gaps between the fins and absorbs heat from the hot water. Hot water, in the tube, dissipates heat by conduction and radiation. This principle is applied for cooling condenser water or steam in an air-cooled heat exchanger.

This type of heat exchanger consists of rectangular bundles (or units) containing several rows of tubes which are horizontally aligned and vertically offset. These tubes may be circular or oval in shape. Fins are provided along the length of the tube for efficient heat transfer.* Hot water or steam flows through the tubes and imparts heat to the metal of the tubes and fins. Air, either induced by fans above the bundles or forced by fans under the bundles, flows through the gaps between successive fins and absorbs heat from the metals.

The advantages of an air-cooled heat exchanger are:

1. Eliminates problems of thermal pollution.
2. Can be used in conjunction with Cooling Towers.
3. Can be used to condense steam directly. The rate of heat transfer for condensing steam (0 - 20 psig) is 130 to 140 BTU's per hour per square foot per degree F.

There is no evaporative water loss in this type of cooling device because cooling is effected by conduction and convection.

DISADVANTAGES

1. The dry-bulb temperature is the cooling limit as opposed to the wet-bulb temperature for the evaporative devices. This results in lower efficiency of the tower because the average summer dry-bulb temperature is higher than the average wet-bulb temperature.

2. Large air movement through the tower is required for the necessary heat transfer.

This type of heat exchanger has been used in industries for cooling varieties of fluids, including steam. Its application to the power industry is fairly recent.

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* Fins can be either triangular or parabolic in cross-sections.

SECTION VII

COST OF WASTE HEAT CONTROL

Various methods of reducing heat discharges were discussed in Section VI. The applicability of these methods must be evaluated on an individual basis, taking into account environmental conditions and economic feasibility. Environmental conditions include: humidity, stream flow, air and water temperatures, and the effects of thermal discharges on the environment. In certain parts of the country large amounts of dilution water with large capacity for absorbing heat without damages are available. In such cases, once-through cooling may be justified. On the other hand, there are areas where land is available at a reasonable cost and water is abundant. Under these circumstances, cooling ponds or spray ponds may be the most efficient and economical solution of the waste heat disposal problem. On the other hand, cooling towers will have to be used in areas where neither the land nor the dilution water is readily available.

COST BREAKDOWN

The total cost of a cooling tower can be divided into four major categories:

A. Initial capital cost.

B. Annual operating cost.

C. Annual maintenance cost.

D. Miscellaneous costs.

1. Initial capital cost includes the following items:

   a. Land acquisition.

   b. Engineering and design.

   c. Construction and installation of the tower.

   d. Other costs, such as alterations or additions needed.

2. Annual operating cost includes items, such as:

   a. Water supply.

   b. Chemicals and chemical treatment.

   c. Power.

   d. Labor costs.

   e. Waste disposal.

   f. Supervision and personnel.

3. Annual maintenance cost consists of following items:

   a. Replacement of materials, such as tools, pipes, timber, packing materials, etc. and labor.

   b. Any special maintenance such as fans, pumps, etc. that may be needed.

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4. Miscellaneous costs include items, such as:

   a. Amortization and depreciation.

   b. Interest.

   c. Taxes.

   d. Insurance.

   e. Rent, if any.

   f. Contingency funds.

It is impractical to assign a dollar value to operation and maintenance costs of cooling towers because of the variety of factors involved.

COST ESTIMATION

Estimates of mechanical draft cooling towers for 504 power plants are shown in Table 12, Appendix III, and in Figures 10 and 11. The type of cooling tower chosen for the estimates is one of the most expensive methods of cooling condenser water. The resulting estimates are, therefore, quite liberal and the actual costs may be less. These estimates include the cost of cooling tower and appurtenances such as water basin, wiring, piping and circulating lines. Operation and maintenance costs are not included.

The assumptions used in cost estimation are as follows:

a. Approach temperature of 10°F.

b. Costs are based on water temperature ranges of 10°F., 15°F., and 20°F. Selection of cooling towers, based on these ranges, will reduce the temperature of the cooling water to the original temperature of intake to the plant.

c. A rough average of $8.00 per gallon per minute of cooling tower capacity(31).

FIGURE 10

CALC. CAPITAL COST OF
MECHANICAL DRAFT
COOLING TOWER.

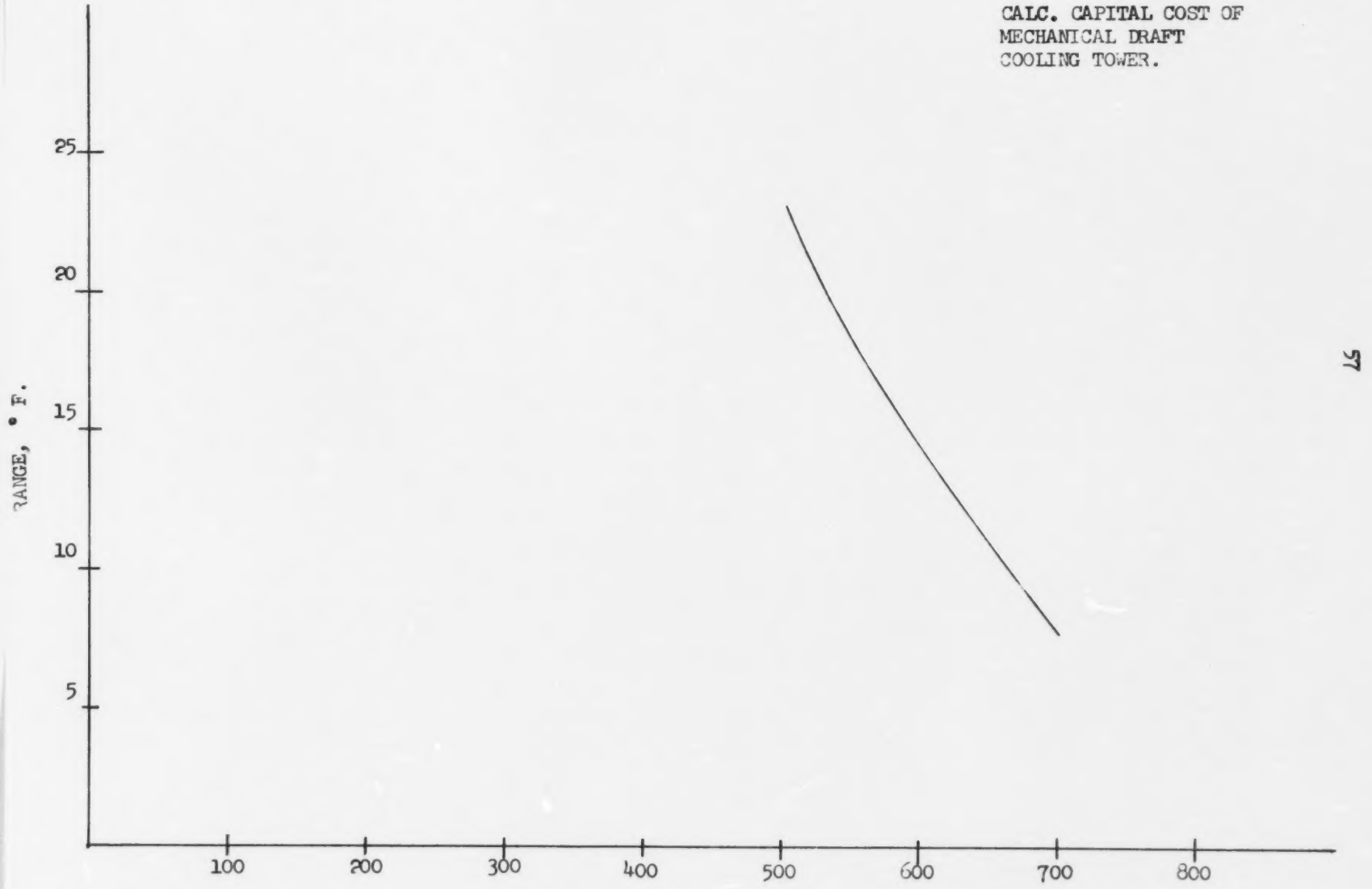
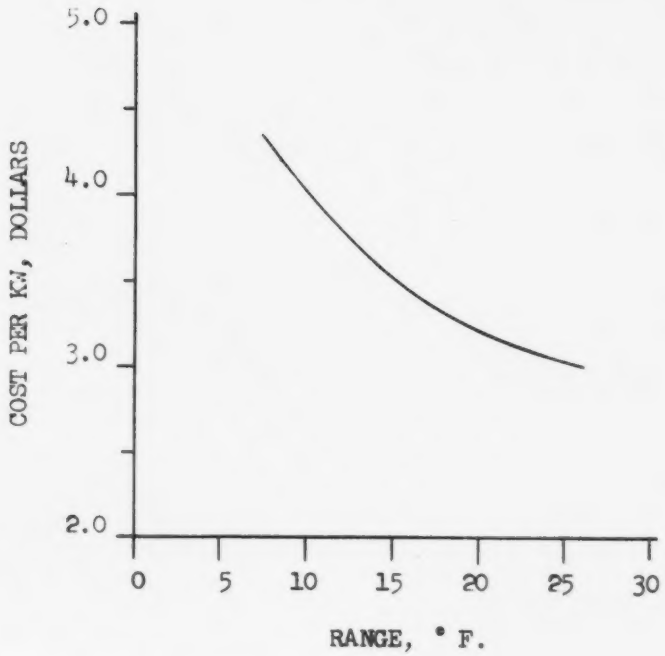


FIGURE 11

CAPITAL COST PER KW OF
MECHANICAL DRAFT COOLING TOWERS



d. Wet bulb temperatures for summer months only because they are considered as critical months from thermal pollution viewpoint.

The formula used in the computation is:

Cost of tower = $8.00 X (Relative Rating Factor) X (GPM of Water Used)

Relative rating factor (RRF) was obtained from the graphs[31] of relative rating factor versus wet-bulb temperature, plotted for various approach temperatures.

Gallons per minute of water to be cooled by the cooling tower were obtained from Table 11, Appendix II.

SUMMARY OF TABLE 12, APPENDIX III

Number of Plants: 504 (10 plants using ocean water were omitted).

Approach temperature: 10°F.

Installed generating capacity: 165,481.7 megawatts.

Range	Cost of Mechanical Draft Tower	Cost/KW
10°F.	$665,000,000	$4.02
15°F.	594,000,000	3.59
20°F.	533,000,000	3.22

The cost of cooling towers for the 10°F. range is greater than that for the 20°F. range by $132,000,000 or $0.80 per KW because larger towers and more water are required for the 10°F. range.

The following estimated capital cost data is given for comparison with the calculated cost of the mechanical draft towers. It is emphasized that the cost figures given below are "ball-park" figures and will vary from location to location.

1. Federal Power Commission[61]: $5.00 per KW.

2. Kolflat[58]: $11 per KW for natural draft wet type tower.

   $ 7 per KW for induced draft wet type tower.

   $25 per KW for natural draft dry type tower.

   $27 per KW for induced draft dry type tower.

Note: Wet type towers are the evaporative type and the dry type are the non-evaporative type of towers.

3. Reed[62]: $ 3 to $3.50 per KW - capital cost for mechanical draft towers.

   $ 4 to $4.50 per KW - capital cost for natural draft hyperbolic towers.

APPENDIX I

A. GLOSSARY OF TERMS USED IN COOLING TOWERS.

B. DESIGN FACTORS.

A. GLOSSARY OF TERMS

1. Air Recirculation

The circulation of hot, humid exhaust vapors from the tower to the air intake of the tower.

2. Approach

The difference between the temperature of the cold water leaving the tower and the wet-bulb temperature of the air entering the tower.

3. Basin

That portion of the tower used for collecting and storing cooled water.

4. Blowdown

The continuous or intermittent wasting of a portion of circulating water to minimize build-up of concentrations of dissolved solids. Expressed either as a percentage of make-up water or as volume per unit time.

5. Chemical Treatment

Treatment of water in cooling tower operations for corrosion control and prevention of decay and deterioration of timber.

6. Distribution System

The function of a distribution system is to spread the incoming hot water uniformly over the top of the tower. Six types of distribution systems generally are used in cooling towers.

They are: Upspray System; Downspray System; Flume Type; Open Pan System; Nonsplash Trough Distributor; and Direct Feed.

7. Drift Eliminators

Drift eliminators are baffles placed above the distribution system in a cooling tower. The hot and humid air, carrying water particles, passes around these baffles and drops the heavier water particles due to centrifugal force.

8. Drift, Windage Loss or Carry-over

The water carried away from the cooling tower by the circulating air, generally expressed as a percentage of make-up water.

9. Evaporation Rate

The rate (volume per unit time) at which water is evaporated to cool the circulating water.

10. Fill or Packing

Materials placed in cooling towers to increase the air and water contact surface and to maintain uniform distribution of air and water throughout the tower.

11. Heat Load

The amount of heat dissipated in a cooling tower, in BTU's per unit of time.

12. Louvers

The sloping boards on the outside of the cooling tower air inlets to prevent spray of water from leaving the tower.

13. Make-up Rate

The quantity of water (volume per unit time) required to replenish the evaporated water and water lost in blowdown and windage losses.

14. Range

The difference between the inlet hot water temperature and the outlet cool water temperature or the number of degrees the water is cooled in the cooling tower.

B. DESIGN FACTORS

The factors to be considered in the design of a cooling tower are:

1. Type of cooling tower, e.g., natural draft or mechanical draft; induced draft or forced draft.
2. Effluent water temperature.
3. Influent water temperature.
4. Design wet bulb temperature.
5. Air velocity through the tower.
6. Tower height.
7. Type of fill and the effective area provided for evaporation.
8. Chemical composition of water.
9. Shape of the tower such as, circular, rectangular, hyperbolic or ellipsoidal.

Many of the above-mentioned factors are subject to the prevailling local conditions. Shape, size, type and height of tower is dependent on the availability of the required land area and the location. The effluent water temperature will be governed by the

water quality standards for the particular stream. Wet bulb temperature, to be used in the design, must be determined from the climatological data for the particular location. Quality of the water is important due to the fouling and corrosion of the metal. Above factors can be used in evaluating the performance of an existing cooling tower.

APPENDIX II

COOLING WATER REQUIREMENTS

TABLE 11 AND FIGURE 8

Note: See Section V for Assumptions and Sample Calculations.

SAMPLE CALCULATION

Name of Plant: Riverton[47]

Plant Location: Riverton, Kansas[47]

Net Electricity Generated during 1965, in Million kilowatt-hours = 790.4[47]

Coal burned, in 1,000 tons of 2,000 lbs. = 33.2[47]

*Coal burned = 66.4×10^6 lbs.

BTU per pound of coal = 12,674 BTU[47]

*Total BTU for the coal burned = $12,674 \times 66.4 \times 10^6$

= $841,553.6 \times 10^6$ BTU

Oil burned, in 1,000 bbls. of 42 gallons = 21.7[47]

*Oil burned = 9.114×10^5 gallons.

BTU per gallon of oil = 150,000 BTU[47]

*Total BTU for the oil burned = $150,000 \times 9.114 \times 10^5$

= $136,710 \times 10^6$ BTU

Gas burned, in million cu. ft. = 8,515.4[47]

*Gas burned = $8,515.4 \times 10^6$ cu. ft.

BTU per cu. ft. of gas = 1,026 BTU[47]

*Total BTU for gas burned = $1,026 \times 8,515.4 \times 10^6$

= $8,736,800.4 \times 10^6$ BTU

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*Total BTU of the fuel (coal, oil and gas)

= $841,553.6 \times 10^6 + 136,710 \times 10^6 +$

$8,736,800.4 \times 10^6$

= $9,715,064 \times 10^6$ BTU

NOTE: * Calculated Values.

*Net Heat Rate of the plant = $\frac{9,715,064 \times 10^6}{790.4 \times 10^6}$ = 12,291.33 BTU/KWH

*Overall Thermal Efficiency of the plant

= $\frac{3,413}{12,291.33} \times 100$ = 27.77%

where:

1 KWH = 3,413 BTU

*Heat Discharged to Cooling Water

= 12,291.33 - 0.175 (12,291.33) - 3,413

= 6,727.34 BTU/KWH

*Cooling Water Required = $\frac{6,727.34}{225,000}$ = 0.0299 cfs/kw/°F. rise in temp.

where:

224,600 is a constant for converting units

*Temperature Rise, ° F.	*Estimated Cooling Water Requirements, Gals/Yr.
10°	63.62×10^9
12°	53.01×10^9
13°	48.94×10^9
15°	42.41×10^9
20°	31.81×10^9

NOTE: * Calculated Values.

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Effi-ciency Percent	HEAT RATE BTU KWH	BTU Rej. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
ALABAMA	Barry	Bucks	Mobile River	5473.8	1399.6	$3.4x10^{13}$	-	-	-	-	-	-	$3.4x10^{13}$	34.81	9803	$1.68x10^{13}$	1.94	1.62	1.50	1.30	0.97
	Chickasaw	Mobile	Chickasaw R.	525.4	277.5	$7.03x10^{13}$	-	-	-	-	-	-	$7.03x10^{13}$	25.78	13270	$3.99x10^{13}$	0.48	0.40	0.37	0.32	0.24
	Gadsden	Gadsden	Coosa River	419.0	94.8	$6.4x10^{12}$	-	-	4387.1	$4.51x10^{12}$	-	-	$5.15x10^{12}$	27.89	12505	$2.84x10^{12}$	0.34	0.28	0.26	0.23	0.17
	Gorgas	Gorgas	Black Warrior River	3301.6	1465.6	$3.38x10^{13}$	-	-	-	-	-	-	$3.38x10^{13}$	33.37	10227	$1.66x10^{13}$	1.99	1.65	1.53	1.32	0.99
	Greene Co.	Demopolis	warrior River	930.8	371.7	$8.71x10^{12}$	-	-	-	-	-	-	$8.71x10^{12}$	36.47	9357	$4.01x10^{12}$	0.48	0.40	0.37	0.32	0.24
	Gaston	Wilson	Coosa																		
	Ernest C.Ville		River	7896.3	3118.5	$7.49x10^{13}$	-	-	-	-	-	-	$7.49x10^{13}$	36.25	9415	$3.44x10^{13}$	4.12	3.43	3.16	2.74	2.06
ARIZONA	Cholla	Joseph City	Artificial Lake	771.6	332.8	$6.94x10^{12}$	-	-	-	-	-	-	$6.94x10^{12}$	35.15	9710	$3.23x10^{12}$	0.39	0.32	0.30	0.26	0.20
	Four Corners	Farmington N. Mex.	Artificial Lake	4286.0	2387.6	$4.3x10^{13}$	-	-	432.5	$4.76x10^{11}$	-	-	$4.34x10^{13}$	33.24	10266	$2.14x10^{13}$	2.56	2.13	1.97	1.71	1.28
	Ocotillo	Tempe	Wells & C.T.	405.3	-	-	-	-	4190.6	$4.54x10^{12}$	-	-	$4.54x10^{12}$	30.48	11198	$2.36x10^{12}$	0.28	0.24	0.22	0.19	0.14
	Saguaro	Red Rock	Wells & C.T.	220.5	-	-	-	-	2775.5	$2.96x10^{12}$	-	-	$2.96x10^{12}$	25.41	13431	$1.69x10^{12}$	0.20	0.17	0.16	0.14	0.10
	Agua Fria	Glendale	Wells & C.T.	1118.3	-	-	5.4	$3.44x10^{10}$	10780.7	$1.17x10^{13}$	-	-	$1.17x10^{13}$	32.56	10481	$5.85x10^{12}$	0.70	0.58	0.54	0.47	0.35
	Kyrene	Tempe	Irr. Ditches & C.T.	190.0	-	-	-	-	2807.5	$2.36x10^{12}$	-	-	$2.36x10^{12}$	27.28	12513	$1.31x10^{12}$	0.16	0.13	0.12	0.11	0.08
	De Mors	Tucson	Irr.Dit.																		
	Petrie		Wells & C.T.	105.4	-	-	-	-	1534.4	$1.64x10^{12}$	-	-	$1.64x10^{12}$	21.97	15533	$9.91.x10^{11}$	0.12	0.10	0.09	0.08	0.06
	Irvington	Tucson	Wells & C.T.	1135.1	-	-	-	-	10913.1	$1.16x10^{13}$	-	-	$1.16x10^{13}$	33.27	10258	$5.73x10^{12}$	0.69	0.57	0.53	0.46	0.34
ARKANSAS	Harvey Couch	Stamps	Wells & C.T.	782.9	-	-	-	-	8736.4	$8.94x10^{13}$	-	-	$8.94x10^{13}$	29.90	11416	$4.70x10^{12}$	0.56	0.47	0.43	0.38	0.28
	Cecil Lynch	N.Little Rock	Wells & C.T.	1272.8	-	-	-	-	14318.1	$1.49x10^{13}$	-	-	$1.49x10^{13}$	29.17	11699	$7.94x10^{12}$	0.95	0.79	0.73	0.63	0.48
	Lake Catherine	Malvern	Ouachita River	966.4	-	-	-	-	11044.8	$1.1x10^{13}$	-	-	$1.1x10^{13}$	29.90	11413	$5.8x10^{12}$	0.68	0.56	0.52	0.45	0.34
	Hamilton Moses	Forrest City	Languille River	465.3	-	-	-	-	5748.0	$5.79x10^{12}$	-	-	$5.79x10^{12}$	27.43	12444	$3.19x10^{12}$	0.38	0.32	0.29	0.26	0.19
	Robert Ritche	Helna	Mississippi R.	2121.6	-	-	-	-	20449.5	$2.09x10^{13}$	-	-	$2.09x10^{13}$	34.68	9841	$9.98x10^{12}$	1.19	1.00	0.92	0.80	0.60
	Jonesboro	Jonesboro	Pond & C.T.	70.5	-	-	6.9	$4.32x10^{10}$	974.9	$1.02x10^{12}$	-	-	$1.06x10^{12}$	22.66	15063	$6.35x10^{11}$	0.08	0.063	0.059	0.051	0.038
CALIFORNIA	Magnolia Blvd.	Burbank	Wells & C.T.	NO DATA AVAILABLE																	
	Olive Ave.	Burbank	Wells & C.T.	567.0	-	-	180.1	$1.15x10^{12}$	5264.9	$5.69x10^{12}$	-	-	$6.84x10^{12}$	28.29	12062	$3.71x10^{12}$	0.44	0.37	0.34	0.30	0.22
	Glendale	Glendale	Wells & C.T.	385.4	-	-	95.9	$6.14x10^{11}$	3924.3	$4.21x10^{12}$	-	-	$4.82x10^{12}$	27.26	12518	$2.67x10^{12}$	0.32	0.27	0.25	0.21	0.16
	Broadway Glenarm	Pasadena	C.T.	469.9	-	-	151.5	$9.47x10^{11}$	4734.6	$5.21x10^{12}$	-	-	$6.16x10^{12}$	27.55	12387	$3.38x10^{12}$	0.41	0.34	0.31	0.27	0.20
	Harbor	Wilmington	Pacific Ocean	1343.3	-	-	693.1	$4.42x10^{12}$	10153.4	$1.10x10^{13}$	-	-	$1.54x10^{13}$	27.54	12391	$8.47x10^{12}$	1.01	0.85	0.80	0.68	0.51
	Haynes	Seal Beach	Pacific Ocean	4897.4	-	-	2800.5	$1.81x10^{13}$	28194.6	$2.68x10^{13}$	-	-	$4.03x10^{13}$	35.83	9524	$1.88x10^{13}$	2.25	1.87	1.73	1.50	1.12
	Scattergood	Playa Del Rey	Pacific Ocean	2068.2	-	-	687.3	$4.38x10^{12}$	15180.0	$1.62x10^{13}$	-	-	$2.06x10^{13}$	34.61	9862	$9.86x10^{12}$	1.18	0.98	0.91	0.79	0.59
ALABAMA (cont4.)	Colbert "A"	Colbert County	Tenn.R. & Pickwick L.	4379.7	1806.2	$4.17x10^{13}$	-	-	-	-	-	-	$4.17x10^{13}$	35.85	9519	$1.95x10^{13}$	2.33	1.94	1.79	1.55	1.16
	Widows Creek "A"	Stevenson	Tenn.R. & Guntersville L.	2971.0	954.5	$2.89x10^{13}$	-	-	-	-	-	-	$2.89x10^{13}$	33.91	10064	$1.11x10^{13}$	1.33	1.11	1.02	0.89	0.67
	Widows Creek "B"	Stevenson	Tenn.R.& Guntersville L.	4638.8	1844.4	$4.33x10^{13}$	-	-	-	-	-	-	$4.33x10^{13}$	36.58	9331	$1.99x10^{13}$	2.38	1.98	1.83	1.59	1.19

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	GAS BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
CALIF.	Valley	Sun Valley	City Water & C.T.	3476.9	-	-	492.6	3.14×10^{12}	21448.0	2.30×10^{13}	-	-	2.62×10^{13}	32.32	10560	1.31×10^{13}	1.57	1.31	1.21	1.05	0.79
	Contra Costa	Anti-och	San Joaquin R.	4259.6	-	-	40.7	3.00×10^{11}	4229.2	4.51×10^{13}	-	-	4.54×10^{13}	32.05	10650	2.29×10^{13}	2.74	2.28	2.11	1.83	1.37
	Humboldt Bay	Eureka	Humboldt Bay	119.6	-	-	7.1	1.34×10^{10}	1027.7	1.09×10^{12}	-	-	1.23×10^{12}	21.15	16134	1.18×10^{12}	0.14	0.12	0.11	0.10	0.071
	Hunters Point	San Francisco	San Francisco Bay	2036.0	-	-	78.2	5.03×10^{11}	20788.8	2.23×10^{13}	-	-	2.28×10^{13}	30.41	11222	1.19×10^{13}	1.42	1.19	1.10	0.95	0.71
	Kern	Bakersfield	Deep Wells & C.T.	149.0	-	-	150.1	2.29×10^{12}	268.6	3.11×10^{11}	-	-	2.60×10^{12}	19.56	17446	1.64×10^{12}	0.20	0.16	0.15	0.13	0.10
	Morro Bay	Morro Bay	Morro Bay	3518.3	-	-	43.5	4.18×10^{12}	97570.0	2.77×10^{13}	-	-	3.19×10^{13}	35.48	9630	1.59×10^{13}	1.91	1.59	1.47	1.27	0.95
	Moss Landing	Moss Landing	Monterey Bay	1427.1	-	-	-	-	15389.5	1.08×10^{13}	-	-	1.08×10^{13}	29.04	11754	8.97×10^{12}	1.07	0.90	0.83	0.72	0.54
	Pittsburg	Contra Costa Co.	Suisun Bay	5647.7	-	-	276.5	1.70×10^{12}	49537.0	5.36×10^{13}	-	-	5.54×10^{13}	34.79	9811	2.64×10^{13}	3.16	2.64	2.43	2.11	1.58
	El Centro	El Centro	Canal & C.T.	93.2	-	-	127.2	8.23×10^{11}	735.1	7.94×10^{11}	-	-	1.62×10^{12}	19.68	17346	1.02×10^{12}	0.12	0.10	0.09	0.08	0.06
	Encina	Carlsbad	Pacific Ocean	1238.0	-	-	325.3	2.10×10^{12}	10093.0	1.09×10^{13}	-	-	1.30×10^{13}	32.45	10518	6.50×10^{12}	0.78	0.65	0.60	0.52	0.39
	South Bay	San Diego	San Diego Bay	2591.0	-	-	454.3	2.92×10^{12}	20707.0	2.24×10^{13}	-	-	2.53×10^{13}	34.97	9760	1.80×10^{13}	1.44	1.20	1.11	0.96	0.72
	Alamitos	Alamitos	Pacific Ocean	5377.9	-	-	2411.3	1.55×10^{13}	34242.5	3.71×10^{13}	-	-	5.26×10^{13}	34.95	9764	2.50×10^{13}	3.00	2.50	2.30	2.00	1.50
	Cool Water		Daggett	Mojave R. & C.T.	749.9	-	-	21.3	1.37×10^{11}	7023.8	7.67×10^{12}	-	-	7.81×10^{12}	32.79	10410	3.88×10^{12}	0.46	0.39	0.36	0.31	0.23
	El Segundo	El Segundo	Pacific Ocean	5740.5	-	-	1373.0	1.20×10^{13}	39275.6	4.26×10^{13}	-	-	5.46×10^{13}	35.91	9505	2.54×10^{13}	3.04	2.54	2.34	2.03	1.52
	Etiwanda	Fontana	Aqueduct & C.T.	5650.0	-	-	1901.4	1.21×10^{13}	39438.4	4.28×10^{13}	-	-	5.49×10^{13}	35.18	9702	2.59×10^{13}	3.11	2.59	2.39	2.07	1.55
	Huntington Beach	Huntington Beach	Pacific Ocean	4624.6	-	-	1339.0	8.51×10^{12}	33848.3	3.64×10^{13}	-	-	4.49×10^{13}	35.18	9701	2.12×10^{13}	2.54	2.12	2.00	1.70	1.27
	Mandalay Beach	Oxnard	Pacific Ocean	2486.1	-	-	25.6	1.64×10^{11}	21973.3	2.30×10^{13}	-	-	2.32×10^{13}	36.66	9311	1.06×10^{13}	1.27	1.06	0.98	0.85	0.64
	Redondo Beach	Redondo Beach	Pacific Ocean	1853.8	-	-	779.3	5.07×10^{12}	13672.3	1.48×10^{13}	-	-	1.99×10^{13}	31.79	10736	1.01×10^{13}	1.21	1.01	0.93	0.81	0.60
	San Bernardino	San Bernardino	Wells & C.T.	643.3	-	-	176.0	1.13×10^{12}	5151.6	5.56×10^{12}	-	-	6.68×10^{12}	32.85	10390	3.32×10^{12}	0.40	0.33	0.31	0.27	0.20
COLO.	Arapahoe	Denver	Wells & C.T.	742.0	183.6	3.67×10^{12}	-	-	6268.1	5.30×10^{12}	-	-	8.97×10^{12}	28.26	12080	4.86×10^{12}	0.58	0.49	0.45	0.39	0.29
	Cameo	Cameo	Gr.Valley Canal & C.T.	328.9	103.9	2.28×10^{12}	-	-	1789.6	1.48×10^{12}	-	-	3.76×10^{12}	29.51	11564	1.99×10^{12}	0.24	0.20	0.18	0.16	0.12
	Cherokee	Denver	S.Platte R. Wells & C.T.	2368.7	782.5	1.73×10^{13}	-	-	8514.2	7.16×10^{12}	-	-	2.45×10^{13}	33.03	10332	1.21×10^{13}	1.45	1.21	1.11	0.97	0.73
	Valmont	Boulder	Valmont Lake	851.3	417.3	8.49×10^{12}	-	-	1132.2	9.31×10^{11}	-	-	9.42×10^{12}	30.85	11064	4.87×10^{12}	0.58	0.49	0.45	0.39	0.29
	Zuni	Denver	S.Platte & C.T.	419.1	98.7	1.87×10^{12}	-	-	4609.7	3.88×10^{12}	-	-	5.75×10^{12}	38.87	13783	3.31×10^{12}	0.58	0.49	0.48	0.39	0.29
	Jim Bullock	Montrose	Uncompahgre R.	78.9	46.4	1.16×10^{12}	-	-	-	-	-	-	1.16×10^{12}	23.21	14709	6.88×10^{12}	0.08	0.07	0.063	0.055	0.041
CONN.	Devon	Devon	Housatonic River	2289.5	947.1	2.40×10^{13}	70.9	4.53×10^{11}	-	-	34.3	4.80×10^{12}	2.93×10^{13}	25.98	13137	1.66×10^{13}	1.98	1.65	1.52	1.32	1.00

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation MW-HR	COAL 1,000 Tons	BTU COAL	OIL 1,000 Bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWHR	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
CONN.	Montville	Montville	Thames River	994.0	420.5	1.1×10^{13}	10.5	6.9×10^{10}	-	-	-	-	1.1×10^{13}	30.89	11048	5.66×10^{12}	0.58	0.56	0.52	0.45	0.34
	Norwalk Harbor	Norwalk Harbor	Long Island Sound	2379.7	874.3	2.29×10^{13}	-	-	-	-	-	-	2.29×10^{13}	32.93	9490	1.05×10^{13}	1.26	1.05	0.97	0.84	0.63
	Middletown	Middletown	Connecticut River	2621.1	947.4	2.51×10^{13}	48.3	1.66×10^{11}	-	-	-	-	2.52×10^{13}	33.45	9827	1.18×10^{13}	1.42	1.18	1.09	0.95	0.71
	South Meadow	Hartford	Conn. River	849.9	287.9	8.6×10^{12}	412.0	2.65×10^{12}	-	-	-	-	8.26×10^{12}	14.91	13702	4.77×10^{12}	0.57	0.48	0.44	0.38	0.29
	Bridgeport Harbor	Bridgeport	Long Island Sound	1657.8	592.6	1.82×10^{13}	-	-	-	-	-	-	1.82×10^{13}	34.88	9786	7.73×10^{12}	0.93	0.77	0.71	0.62	0.46
	English	New Haven	Long Island Sound	451.4	-	-	1049.2	6.71×10^{12}	-	-	-	-	6.71×10^{12}	22.96	14867	4.00×10^{12}	0.48	0.40	0.37	0.32	0.24
	Steel Point	Bridgeport	Long Island Sound	111.5	4.9	1.38×10^{11}	864.5	5.44×10^{12}	-	-	-	-	5.58×10^{12}	19.04	17927	3.54×10^{12}	0.42	0.35	0.33	0.28	0.21
DELAWARE	Edgemoor	Wilmington	Delaware R.	1228.3	419.0	1.12×10^{13}	-	-	1831.9	1.91×10^{12}	-	-	1.31×10^{13}	31.95	10681	6.63×10^{12}	0.79	0.66	0.61	0.53	0.40
	Indian River	Millsboro	Indian River	1020.8	388.5	1.00×10^{13}	-	-	-	-	-	-	1.00×10^{13}	34.68	9841	4.80×10^{12}	0.58	0.48	0.44	0.38	0.29
D.C.	Benning	Wash., D.C.	Anacostia R.	422.0	286.3	5.90×10^{12}	-	-	-	-	-	-	5.90×10^{12}	24.39	13993	3.43×10^{12}	0.41	0.34	0.32	0.27	0.21
	Buzzards Point	Wash., D.C.	Anacostia R.	138.7	73.0	2.00×10^{12}	-	-	-	-	-	-	2.00×10^{12}	23.64	14439	1.18×10^{12}	0.14	0.12	0.11	0.094	0.071
FLORIDA	Avon Park	Avon Park	Lake Lotella	182.8	-	-	-	-	2143.9	2.21×10^{12}	-	-	2.21×10^{12}	28.78	11859	1.19×10^{12}	0.14	0.12	0.11	0.095	0.071
	Bartow	St. Petersburg	Tampa Bay	2413.0	-	-	3489.2	2.20×10^{13}	1740.5	1.80×10^{12}	-	-	2.38×10^{13}	34.63	9857	1.14×10^{13}	1.36	1.14	1.05	0.91	0.68
	Bayboro	St. Petersburg	Tampa Bay	186.3	-	-	412.5	2.62×10^{12}	-	-	-	-	2.62×10^{12}	24.27	14063	1.53×10^{12}	0.18	0.15	0.14	0.12	0.09
	Higgins	Oldsmar	Tampa Bay	536.7	-	-	249.6	1.58×10^{12}	4759.5	4.89×10^{12}	-	-	6.47×10^{12}	28.32	12050	3.50×10^{12}	0.42	0.35	0.32	0.28	0.21
	Suwanee	Ellaville	Suwanee River	540.0	-	-	30.9	2.44×10^{11}	5576.4	5.87×10^{12}	-	-	6.12×10^{12}	30.12	11330	3.30×10^{12}	0.38	0.32	0.30	0.26	0.19
	Turner, G.E.	Enterprise	Lake Monroe	999.8	-	-	11.6	7.29×10^{10}	10789.6	1.11×10^{13}	-	-	1.12×10^{13}	30.50	11186	5.82×10^{12}	0.70	0.58	0.54	0.46	0.35
	Cape Kennedy	Cocoa	Indian River	1372.1	-	-	2391.0	1.50×10^{13}	-	-	-	-	1.50×10^{13}	35.79	9537	7.00×10^{12}	0.84	0.70	0.65	0.56	0.42
	Ft. Meyers	Ft. Meyers	Caloosahatchee R.	457.5	-	-	746.7	4.73×10^{12}	-	-	-	-	4.73×10^{12}	33.04	10329	2.34×10^{12}	0.28	0.23	0.22	0.19	0.14
	Lauderdale	Dania	Dania Canal Cut-off	706.7	-	-	359.9	2.27×10^{12}	5360.7	5.36×10^{12}	-	-	7.61×10^{12}	31.59	10803	3.69×10^{12}	0.47	0.39	0.36	0.31	0.23
	Palatka	E. Palatka	St. John's River	427.5	-	-	-	-	4700.0	4.70×10^{12}	-	-	4.70×10^{12}	31.04	10994	2.48×10^{12}	0.029	0.024	0.022	0.19	0.15
	Cutler	Cutler	Biscayne Bay	1090.6	-	-	6.4	4.04×10^{11}	12751.1	1.28×10^{13}	-	-	1.28×10^{13}	29.10	11727	6.83×10^{12}	0.82	0.68	0.63	0.55	0.41

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWHR	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWHR	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
FLORIDA	Port Everglades	Port Everglades	Atlantic Ocean	5665.9	-	-	5491.9	5.35×10^{13}	-	-	-	-	5.35×10^{13}	35.53	9606	2.51×10^{13}	3.01	2.51	2.31	2.00	1.50
	Riviera	Riviera	Lake Worth	2835.7	-	-	3116.2	1.95×10^{13}	8286.8	8.23×10^{12}	-	-	2.78×10^{13}	34.86	9791	1.32×10^{13}	1.58	1.32	1.22	1.06	0.79
	Sanford	Sanford	St. John's River	576.0	-	-	240.3	1.24×10^{12}	4969.1	4.97×10^{12}	-	-	6.21×10^{12}	31.68	10775	3.15×10^{12}	0.38	0.32	0.29	0.25	0.19
	Crist	Pensacola	Escambia R.	1303.0	455.7	1.16×10^{13}	-	-	1716.2	1.78×10^{12}	-	-	1.33×10^{13}	33.36	10230	6.55×10^{12}	0.78	0.65	0.60	0.52	0.39
	Scholz	Sneads	Apalachicola R.	267.9	128.2	3.27×10^{12}	-	-	-	-	-	-	3.23×10^{12}	28.35	12037	1.75×10^{12}	0.21	0.17	0.16	0.14	0.11
	Lansing Smith	Panama City	North Bay	507.6	212.3	4.99×10^{12}	-	-	-	-	-	-	4.99×10^{12}	34.75	9820	2.38×10^{12}	0.29	0.24	0.22	0.19	0.14
	Gannon, F.J.	Tampa	Tampa Bay	3441.0	1586.4	3.54×10^{13}	-	-	-	-	-	-	3.54×10^{13}	33.21	10278	1.74×10^{13}	2.09	1.74	1.61	1.39	1.04
	Hooker's Point	Tampa	Tampa Bay	687.6	-	-	1272.2	8.02×10^{12}	-	-	-	-	8.02×10^{12}	26.71	12776	4.47×10^{12}	0.54	0.45	0.41	0.36	0.27
	Kennedy, J.D.	Jackson-ville	St. John's River	1179.3	-	-	2081.0	1.30×10^{13}	-	-	-	-	1.30×10^{13}	30.94	11031	6.71×10^{12}	0.80	0.67	0.62	0.54	0.40
	Southside	Jackson-ville	St. John's River	1328.9	-	-	2901.5	1.37×10^{13}	-	-	-	-	1.37×10^{13}	33.03	10333	6.79×10^{12}	0.81	0.68	0.63	0.54	0.41
	Fort Pierce	Fort Pierce	Indian River	113.0	-	-	156.5	9.84×10^{11}	575.2	5.92×10^{11}	-	-	1.58×10^{13}	24.46	13954	9.15×10^{11}	0.11	0.091	0.084	0.073	0.055
	Key West	Key West	Wells	177.2	-	-	390.3	2.44×10^{12}	-	-	-	-	2.44×10^{12}	24.77	13779	1.41×10^{12}	0.17	0.14	0.13	0.11	0.084
	Indian River	Indian River City	Indian River	1014.4	-	-	729.9	4.60×10^{12}	6003.3	6.18×10^{12}	-	-	1.08×10^{13}	32.10	10634	5.44×10^{12}	0.65	0.54	0.50	0.43	0.33
	St. Mark's	Tallahassee	St. Mark's River	303.4	-	-	74.2	4.80×10^{11}	3515.0	3.70×10^{12}	-	-	4.18×10^{12}	28.79	13770	2.41×10^{12}	0.29	0.24	0.22	0.19	0.14
GEORGIA	Arkwright	Bibb County	Ocmulgee River	673.4	338.5	8.31×10^{12}	-	-	-	-	-	-	8.31×10^{12}	27.65	12344	4.56×10^{12}	0.55	0.46	0.42	0.36	0.27
	Atkinson	Cobb Co.	Chattahoochee R.	796.0	395.4	9.86×10^{12}	-	-	-	-	-	-	9.86×10^{12}	27.54	12393	5.42×10^{12}	0.65	0.54	0.50	0.43	0.33
	Branch	Cobb	Lake																		
	Barllee	Co.	Sinclair	992.1	365.9	9.26×10^{12}	-	-	-	-	-	-	9.26×10^{12}	36.57	9334	4.25×10^{12}	0.51	0.42	0.39	0.34	0.26
	Hammond	Rome	Coosa River	1573.1	646.8	1.58×10^{13}	-	-	-	-	-	-	1.58×10^{13}	34.07	10018	7.63×10^{12}	0.91	0.76	0.70	0.61	0.46
	McDonough	Smyrna	Chattahoochee R.	3512.7	1347.0	3.36×10^{13}	-	-	-	-	-	-	3.36×10^{13}	35.67	9569	1.57×10^{13}	1.88	1.57	1.45	1.26	0.94
	Jack McManus	Brunswick	Turtle River	655.7	269.0	6.93×10^{12}	-	-	-	-	-	-	6.93×10^{12}	32.30	10568	3.48×10^{12}	0.42	0.35	0.32	0.28	0.21
	Mitchell	Dougherty County	Flint River	900.9	335.9	8.52×10^{12}	-	-	-	-	-	-	8.52×10^{12}	36.08	9459	3.96×10^{12}	0.47	0.40	0.36	0.32	0.24
	Yates	Whitesburg	Chattahoochee River	2837.0	1203.4	2.95×10^{13}	-	-	-	-	-	-	2.95×10^{13}	32.87	10383	1.46×10^{13}	1.75	1.46	1.35	1.17	0.88
	Port Wentworth	Port Wentworth	Savannah R.	943.4	347.5	9.16×10^{12}	-	-	-	-	-	-	9.16×10^{12}	35.16	9706	4.33×10^{12}	0.52	0.43	0.40	0.35	0.26

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	NET Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Rej. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
ILLINOIS	Edwards, E.D.	Bartonville	Illinois River	928.9	486.6	8.98×10^{12}	-	-	-	-	-	-	8.98×10^{12}	35.30	9669	4.8×10^{12}	0.51	0.42	0.39	0.34	0.25
	Wallace, R.S.	East Peoria	Illinois River	1117.3	608.0	1.25×10^{13}	-	-	121.5	1.19×10^{11}	-	-	1.29×10^{13}	29.56	11544	6.83×10^{12}	0.69	0.68	0.63	0.55	0.41
	Sabrooke	Rockford	Rock River	813.6	180.6	4.09×10^{12}	-	-	4861.1	5.12×10^{12}	-	-	9.21×10^{12}	30.16	11317	4.8×10^{12}	0.58	0.48	0.44	0.39	0.29
	Grand Tower	Grand Tower	Mississippi R.	1118.8	519.5	1.18×10^{13}	-	-	-	-	-	-	1.18×10^{13}	32.51	10500	5.87×10^{12}	0.70	0.59	0.54	0.47	0.35
	Hutsonville	Hutsonville	Wabash River	1060.5	473.5	1.11×10^{13}	-	-	-	-	-	-	1.11×10^{13}	32.68	10444	5.58×10^{12}	0.66	0.55	0.51	0.44	0.33
	Meredosia	Meredosia	Illinois River	1444.7	686.4	1.43×10^{13}	-	-	-	-	-	-	1.43×10^{13}	34.50	9893	6.86×10^{12}	0.69	0.68	0.63	0.55	0.41
	Crawford	Chicago	Chicago S. & S.Canal	3955.8	1748.0	3.57×10^{13}	-	-	8468.6	2.59×10^{12}	-	-	3.83×10^{13}	35.87	9676	1.81×10^{13}	2.16	1.80	1.66	1.44	1.08
	Fisk	Chicago	Chicago River	2157.0	964.0	1.96×10^{13}	-	-	8665.6	2.73×10^{12}	-	-	2.24×10^{13}	32.90	10373	1.11×10^{13}	1.33	1.11	1.02	0.89	0.66
	Joliet	Joliet	Des Plaines River	5593.5	8663.0	5.58×10^{13}	-	-	-	-	-	-	5.58×10^{13}	36.80	9581	2.70×10^{13}	3.23	2.69	2.48	2.15	1.61
	Powerton	Pekin	Illinois River	771.4	526.4	1.06×10^{13}	-	-	-	-	-	-	1.06×10^{13}	28.75	13793	6.15×10^{12}	0.74	0.61	0.57	0.49	0.37
	Ridgeland	Stickney	Chicago S. & S.Canal	3490.6	1764.7	3.57×10^{13}	-	-	1410.1	1.48×10^{12}	-	-	3.72×10^{13}	32.06	10646	1.87×10^{13}	2.24	1.87	1.73	1.50	1.12
	Waukegan	Waukegan	Lake Michigan	4945.9	1874.4	4.07×10^{13}	-	-	7977.5	8.41×10^{12}	-	-	4.91×10^{13}	36.39	9383	2.36×10^{13}	2.83	2.35	2.17	1.88	1.41
	Will County	Lockport	Chicago S. & S.Canal	6686.1	3157.9	6.48×10^{13}	-	-	-	-	-	-	6.48×10^{13}	35.53	9606	3.08×10^{13}	3.61	3.01	2.78	2.41	1.81
	State Line	Hammond	Lake Michigan	4736.3	1659.1	3.66×10^{13}	-	-	9037.6	9.46×10^{12}	-	-	4.60×10^{13}	35.14	9721	2.18×10^{13}	2.61	2.17	2.01	1.74	1.30
	Joppa	Joppa	Ohio R.	8858.0	3466.9	8.01×10^{13}	-	-	-	-	-	-	8.01×10^{13}	35.19	9699	3.79×10^{13}	4.54	3.78	3.49	3.03	2.27
	Lakeside	Springfield	Springfield Lake	476.3	308.2	6.44×10^{12}	-	-	-	-	-	-	6.44×10^{12}	25.85	13214	3.68×10^{12}	0.44	0.37	0.34	0.29	0.22
	Havana	Havana	Illinois River	480.2	305.5	6.86×10^{12}	-	-	-	-	-	-	6.86×10^{12}	26.19	13033	3.58×10^{12}	0.42	0.35	0.33	0.28	0.21
	Hennepin	Hennepin	Illinois River	1679.7	765.3	1.63×10^{13}	-	-	-	-	-	-	1.63×10^{13}	35.09	9727	7.75×10^{12}	0.93	0.77	0.71	0.62	0.46
	Vermilion	Oakwood	Reservoir & C.T.	974.8	467.7	1.00×10^{13}	-	-	-	-	-	-	1.00×10^{13}	32.52	10495	5.11×10^{12}	0.61	0.51	0.47	0.41	0.31
	Wood R.	Wood River	Mississippi R.	3421.0	1490.3	3.39×10^{13}	-	-	1806.0	1.05×10^{12}	-	-	3.50×10^{13}	33.38	10225	1.78×10^{13}	2.06	1.71	1.58	1.37	1.03
	Oakdale	Nauvoo	Mississippi R.	335.5	237.4	5.61×10^{12}	-	-	-	-	-	-	5.61×10^{12}	20.42	16718	3.48×10^{12}	0.42	0.35	0.32	0.26	0.21
	Venice No.2	East St.Louis	Mississippi R.	2390.4	1194.8	2.78×10^{13}	-	-	2819.0	2.95×10^{12}	-	-	3.01×10^{13}	27.07	12609	1.67×10^{13}	2.00	1.67	1.54	1.33	1.00
	Meramec	St.Louis County	Mississippi R.	6860.3	2465.2	5.51×10^{13}	-	-	6532.6	6.83×10^{12}	-	-	6.19×10^{13}	34.50	9893	2.97×10^{13}	3.56	2.97	2.74	2.37	1.78
	Moline	Moline	Mississippi R.	270.2	8.6	1.89×10^{11}	-	-	323.7	3.38×10^{12}	-	-	3.57×10^{12}	25.84	13210	2.08×10^{12}	0.24	0.20	0.19	0.16	0.12
INDIANA	Clifty Creek	Madison	Ohio River	9981.3	4185.0	9.80×10^{13}	-	-	-	-	-	-	9.80×10^{13}	36.87	9257	4.82×10^{13}	5.03	4.19	3.87	3.35	2.51
	Breed	Sullivan	Wabash River	3141.5	1250.7	2.81×10^{13}	-	-	-	-	-	-	2.81×10^{13}	38.21	8930	1.84×10^{13}	1.49	1.24	1.14	0.99	0.74
	Tanner's Creek	Lawrenceburg	Ohio River	6489.1	8533.7	5.83×10^{13}	-	-	-	-	-	-	5.83×10^{13}	37.98	8951	2.60×10^{13}	3.11	2.59	2.39	2.07	1.55
	Twin Branch	Mishawaka	St. Joseph River	837.5	417.7	9.38×10^{12}	-	-	-	-	-	-	9.38×10^{12}	30.67	11128	4.83×10^{12}	0.58	0.48	0.45	0.39	0.29
	Bailey	Dune Acres	Lake Michigan	1299.4	486.1	1.11×10^{13}	-	-	975.9	9.76×10^{11}	-	-	1.21×10^{13}	35.65	9574	5.69×10^{12}	0.68	0.56	0.52	0.45	0.34
	Dean	Gary	Lake Michigan	8934.0	1246.4	8.77×10^{13}	-	-	858.5	8.56×10^{11}	1.9	1.14×10^{9}	8.86×10^{13}	35.03	9743	1.36×10^{13}	1.62	1.35	1.25	1.08	0.81
	Mitchell	Michigan City	Michigan	380.7	117.9	2.59×10^{12}	-	-	8050.6	2.05×10^{12}	-	-	4.64×10^{12}	27.98	12198	2.53×10^{12}	0.30	0.25	0.23	0.20	0.15
	Pritchard, H.T.	Centertown	White River	1606.9	760.6	1.78×10^{13}	-	-	-	-	-	-	1.78×10^{13}	31.91	10695	8.69×10^{12}	1.04	0.87	0.80	0.69	0.52
	Stout, E.W.	Indianapolis	Wells & C.T.	1611.2	714.1	1.64×10^{13}	-	-	-	-	-	-	1.64×10^{13}	33.47	10198	8.06×10^{12}	0.96	0.80	0.74	0.64	0.48
	Dresser	Terre Haute	Wabash River	381.0	258.1	5.59×10^{12}	-	-	-	-	-	-	5.59×10^{12}	23.87	14666	3.31×10^{12}	0.40	0.33	0.31	0.26	0.20
	Edwardsport	Edwardsport	White River	590.1	350.8	7.76×10^{12}	-	-	-	-	-	-	7.76×10^{12}	25.96	13149	4.39×10^{12}	0.53	0.44	0.40	0.35	0.26

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWHR	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 BTU cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWHR	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{12} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
INDIANA	Gallagher	New Albany	Ohio River	3695.1	1698.4	$3.91x10^{13}$	-	-	-	-	-	-	$3.91x10^{13}$	34.01	10035	$1.50x10^{13}$	2.27	1.89	1.75	1.51	1.14
	Wabash River	Terre Haute	Wabash River	2974.7	1371.6	$3.06x10^{13}$	-	-	-	-	-	-	$3.06x10^{13}$	33.91	10077	$1.51x10^{13}$	1.80	1.50	1.39	1.00	0.90
	Culley, F.B.	Tanbeetown	Ohio River	867.1	139.4	$2.93x10^{12}$	-	-	-	-	-	-	$2.93x10^{12}$	31.09	10977	$1.51x10^{12}$	0.18	0.15	0.14	0.12	0.09
	Ohio River	Evansville	Ohio River	378.4	258.9	$5.28x10^{12}$	-	-	-	-	-	-	$5.28x10^{12}$	34.40	13966	$3.04x10^{12}$	0.36	0.30	0.28	0.24	0.18
	White River Water Valley	Richmond	White River	200.2	101.0	$2.35x10^{12}$	-	-	-	-	-	-	$2.35x10^{12}$	29.14	11714	$1.35x10^{12}$	0.15	0.13	0.12	0.10	0.08
IOWA	Kapp, Milton (Beaver Channel)	Clinton	Mississippi River	123.8	48.7	$1.06x10^{12}$	-	-	648.6	$6.49x10^{11}$	-	-	$1.72x10^{12}$	24.58	13909	$9.99x10^{11}$	0.12	0.10	0.090	0.08	0.06
	Dubuque	Dubuque	Mississippi R.	453.3	215.3	$4.68x10^{12}$	-	-	1378.1	$1.38x10^{12}$	-	-	$6.06x10^{12}$	24.73	13809	$3.62x10^{12}$	0.43	0.36	0.33	0.29	0.22
	Lansing	Lansing	Mississippi R.	317.1	181.6	$4.05x10^{12}$	-	-	-	-	-	-	$4.05x10^{12}$	26.74	12763	$2.86x10^{12}$	0.27	0.23	0.21	0.18	0.14
	Prairie Creek	Cedar Rapids	Cedar River	442.3	231.4	$4.91x10^{12}$	-	-	478.8	$5.08x10^{11}$	-	-	$5.41x10^{12}$	27.91	12229	$2.95x10^{12}$	0.35	0.30	0.27	0.24	0.18
	Sutherland	Marshalltown	Iowa River	872.8	166.3	$3.09x10^{12}$	-	-	6700.2	$6.71x10^{12}$	-	-	$9.81x10^{12}$	30.38	11235	$5.11x10^{12}$	0.61	0.51	0.47	0.41	0.31
	Riverside	Iowaman	Mississippi R.	1441.4	388.5	$8.14x10^{12}$	-	-	8354.8	$8.81x10^{12}$	-	-	$1.69x10^{13}$	29.04	11753	$9.06x10^{12}$	1.08	0.90	0.83	0.72	0.54
	Council Bluff	Council Bluff	Missouri River	768.9	148.6	$3.48x10^{12}$	-	-	4738.6	$4.71x10^{12}$	-	-	$8.19x10^{12}$	31.81	10789	$4.15x10^{12}$	0.50	0.41	0.38	0.33	0.25
	Des Moines No. 9	Des Moines	Des Moines River	1951.1	327.9	$6.09x10^{12}$	-	-	10083.6	$1.01x10^{13}$	-	-	$1.62x10^{13}$	26.44	12910	$9.06x10^{12}$	1.08	0.90	0.84	0.73	0.54
	Maynard Street	Waterloo	Cedar River	358.5	78.5	$1.85x10^{12}$	-	-	2776.1	$2.75x10^{12}$	-	-	$4.60x10^{12}$	26.60	12831	$2.57x10^{12}$	0.31	0.26	0.24	0.21	0.15
	Neal	Salix	Missouri River	776.7	130.5	$3.06x10^{12}$	-	-	4513.5	$4.5x10^{12}$	-	-	$7.56x10^{12}$	35.06	9734	$3.59x10^{12}$	0.43	0.36	0.33	0.29	0.22
	Bridgeport	Eddyville	Des Moines R. & C.T.	398.6	221.3	$5.49x10^{12}$	-	-	-	-	-	-	$5.49x10^{12}$	24.79	13767	$3.17x10^{12}$	0.38	0.32	0.29	0.25	0.19
	Muscatine	Muscatine	Mississippi R.	297.9	129.5	$2.98x10^{12}$	-	-	803.2	$8.13x10^{11}$	-	-	$3.13x10^{12}$	24.84	13739	$1.81x10^{12}$	0.22	0.18	0.17	0.14	0.11
KANSAS	Colby No. 2	Colby	Wells & C.T.	47.2	-	-	0.7	$4.41x10^{9}$	889.5	$7.88x10^{11}$	-	-	$7.98x10^{11}$	20.33	16789	$4.91x10^{11}$	0.06	0.05	0.045	0.04	0.03
	Rose Bench	Hill City	Wells & C.T. Spring	56.9	-	-	0.5	$3.15x10^{9}$	858.3	$7.64x10^{11}$	-	-	$7.67x10^{11}$	25.31	13488	$4.59x10^{11}$	0.053	0.044	0.04	0.035	0.026
	Riverton	Riverton	River	790.4	33.2	$0.48x10^{11}$	22.7	$1.37x10^{11}$	8515.4	$8.74x10^{12}$	-	-	$9.78x10^{12}$	37.77	12991	$5.38x10^{12}$	0.64	0.53	0.49	0.40	0.32
	Riverton	Riverton	-	93.8	-	-	-	-	1216.8	$1.45x10^{12}$	-	-	$1.45x10^{12}$	28.09	15458	$8.76x10^{11}$	0.11	0.09	0.08	0.07	0.05
	Gordon Evans	Wichita	Arkansas River	1030.2	-	-	-	-	9755.0	$1.08x10^{13}$	-	-	$1.08x10^{13}$	30.59	9667	$4.87x10^{12}$	0.58	0.49	0.45	0.39	0.29
	Murray Gills	Wichita	Wells & C.T. Arkansas River																		
	Brooke	Brooke	& C.T. Brooke River Spray Ponds & C.T.	2046.2	-	-	-	-	20336.7	$2.18x10^{13}$	-	-	$2.18x10^{13}$	32.92	10366	$1.05x10^{13}$	1.26	1.05	0.97	0.84	0.63
				805.9	0.9	$4.38x10^{9}$	86.6	$1.71x10^{11}$	2865.1	$2.34x10^{12}$	-	-	$2.52x10^{12}$	27.89	12239	$1.38x10^{12}$	0.17	0.14	0.13	0.11	0.08

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation MW-HRS	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Effi-ciency Percent	HEAT RATE BTU per KWH	BTU Rej. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	15° F.	13° F.	18° F.	20° F.
KANSAS	Ripley	Wichita	Little Arkansas & C.T.	166.6	-	-	-	-	8809.4	9.30×10^{12}	-	-	9.30×10^{12}	28.77	13779	1.13×10^{12}	0.16	0.13	0.12	0.11	0.08
	Hutchinson Sta. # 2	Hutchinson	Well & C.T.	898.0	-	-	1.6	1.03×10^{10}	9160.3	8.98×10^{12}	-	-	8.99×10^{12}	31.89	10910	4.60×10^{12}	0.55	0.46	0.40	0.37	0.28
	Lawrence	Lawrence	Kansas River Wells & C.T.	985.5	65.3	1.64×10^{12}	3.5	2.18×10^{10}	8686.6	8.69×10^{12}	-	-	9.95×10^{12}	31.61	10797	5.06×10^{12}	0.61	0.51	0.47	0.40	0.30
	Riverside (Abilene)	Abilene	Smoky Hill River	68.8	-	-	9.6	1.59×10^{10}	880.9	8.67×10^{11}	-	-	8.83×10^{11}	28.97	14063	5.13×10^{11}	0.060	0.051	0.047	0.041	0.031
	Tecumseh	Tecumseh	Missouri River	1111.4	99.5	2.06×10^{12}	1.6	9.91×10^{9}	11948.1	1.21×10^{13}	-	-	1.44×10^{13}	31.71	10950	7.37×10^{12}	0.88	0.74	0.68	0.59	0.44
	Fort Dodge	Dodge City	Wells & C.T.	149.1	-	-	1.6	9.27×10^{10}	8996.0	9.08×10^{12}	-	-	9.10×10^{12}	33.54	10500	1.84×10^{12}	0.15	0.12	0.11	0.10	0.07
	Cimarron R.	Liberal	C.T.	266.4	-	-	-	-	3639.1	3.44×10^{12}	-	-	3.44×10^{12}	26.44	12909	1.93×10^{12}	0.23	0.19	0.18	0.15	0.12
	Arthur Mullergren	Great Bend	Wells & C.T.	536.4	-	-	-	-	6191.8	5.96×10^{12}	-	-	5.96×10^{12}	30.70	11116	3.09×10^{12}	0.37	0.31	0.28	0.25	0.19
	Kaw River	Kansas City	Kansas River	737.7	207.6	4.89×10^{12}	-	-	3798.1	3.52×10^{12}	-	-	8.40×10^{12}	29.96	11391	4.41×10^{12}	0.53	0.44	0.41	0.35	0.26
	Quindaro No. 2	Kansas City	Kansas River	354.2	81.0	1.98×10^{12}	-	-	3513.6	3.32×10^{12}	-	-	5.30×10^{12}	22.80	14970	3.17×10^{12}	0.38	0.32	0.29	0.25	0.19
		McPherson	Wells & C.T.	107.2	NO DATA AVAILABLE																
KENTUCKY	Big Sandy	Louisa	Big Sandy R. & C.T.	2165.2	779.5	1.9×10^{13}	-	-	-	-	-	-	1.9×10^{13}	30.12	8954	8.61×10^{12}	1.03	0.86	0.79	0.69	0.52
	Brown, E.W.	Burgin	Dix Dam Resv'r. & C.T.	1055.3	434.5	1.06×10^{13}	-	-	-	-	-	-	1.06×10^{13}	33.96	10051	5.15×10^{12}	0.62	0.51	0.47	0.41	0.31
	Green River	Carrollton	Green River	941.5	445.7	1.04×10^{13}	-	-	-	-	-	-	1.04×10^{13}	30.89	11049	5.37×10^{12}	0.64	0.54	0.49	0.43	0.32
	Cane Run	Louisville	Ohio River	3165.0	1370.4	3.15×10^{13}	-	-	133.5	1.38×10^{11}	-	-	3.17×10^{13}	34.12	10003	1.53×10^{13}	1.83	1.53	1.41	1.22	0.92
	Paddy's Run	Louisville	Ohio River	590.0	330.3	7.64×10^{12}	-	-	3.3	3.42×10^{9}	-	-	7.64×10^{12}	26.35	12951	4.29×10^{12}	0.51	0.43	0.40	0.34	0.26
LOUISIANA	Coughlin	St. Landry	Bayou & Art.Lake	987.5	-	-	-	-	9902.7	1.08×10^{13}	-	-	1.08×10^{13}	31.31	10900	5.51×10^{12}	0.66	0.55	0.51	0.44	0.33
	Teche	Baldwin	Canal	380.1	-	-	-	-	3908.1	4.15×10^{12}	-	-	4.15×10^{12}	31.23	10930	2.13×10^{12}	0.26	0.21	0.20	0.17	0.13
	Louisiana Sta. No. 2	Baton Rouge	Well & C.T.	645.2	-	-	-	-	7625.9	8.11×10^{12}	-	-	8.11×10^{12}	27.14	12576	4.50×10^{12}	0.54	0.45	0.41	0.36	0.27
	Nelson, Roy S.	Westlake	Wells & C.T.	1672.7	-	-	-	-	16502.9	1.78×10^{13}	-	-	1.78×10^{13}	32.09	10634	8.97×10^{12}	1.07	0.89	0.83	0.72	0.54
	Willow Glen	St. Gabriel	Mississippi	2997.9	-	-	-	-	21262.3	2.3×10^{13}	-	-	2.3×10^{13}	34.09	10012	1.11×10^{13}	1.33	1.11	1.03	0.89	0.67
	Little Gypsy	Muntz	Mississippi	1568.1	-	-	-	-	14286.9	1.48×10^{13}	-	-	1.48×10^{13}	35.19	9698	7.19×10^{12}	0.86	0.72	0.66	0.57	0.43
	Nine Mile Point	Westwego	Mississippi River	1836.8	-	-	-	-	18606.7	1.98×10^{13}	-	-	1.98×10^{13}	31.61	10799	1.01×10^{13}	1.21	1.01	0.93	0.81	0.60
	Sterlington	Sterlington	Ouachita River	1868.1	-	-	-	-	19398.9	1.95×10^{13}	-	-	1.95×10^{13}	32.74	10426	9.69×10^{12}	1.16	0.97	0.89	0.77	0.58
	Market Street	New Orleans	Mississippi R.	254.7	-	-	-	-	4098.1	4.38×10^{12}	-	-	4.38×10^{12}	22.96	14866	2.61×10^{12}	0.31	0.26	0.24	0.21	0.16
	Michoud,	New Orleans	Michoud Canal	1831.9	-	-	-	-	17154.2	1.86×10^{13}	-	-	1.86×10^{13}	33.69	10132	9.06×10^{12}	1.08	0.90	0.83	0.72	0.54
	Patterson, A.B.	New Orleans	Industrial Canal	552.6	-	-	-	-	6355.7	6.88×10^{12}	-	-	6.88×10^{12}	27.40	12456	3.79×10^{12}	0.45	0.38	0.35	0.30	0.23
	Lieberman	Moorings-port	Cobb Lake	1222.9	-	-	-	-	11963.8	1.26×10^{13}	-	-	1.26×10^{13}	33.04	10331	6.25×10^{12}	0.75	0.62	0.58	0.50	0.37
KENTUCKY	Paradise	Drakesboro	Green River	7775.1	3355.5	6.96×10^{13}	-	-	-	-	-	-	6.96×10^{13}	38.11	8955	3.09×10^{13}	3.70	3.08	2.85	2.47	1.85
	Shawnee	Paducah	Ohio River	10414.1	4383.1	1.00×10^{14}	-	-	-	-	-	-	1.00×10^{14}	35.41	9639	4.73×10^{13}	5.66	4.72	4.35	3.77	2.83

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
MAINE	Mason	Wiscasset	Atlantic Ocean	640.5	-	-	1114.5	8.26×10^{12}	-	-	-	-	8.26×10^{12}	26.46	12900	4.63×10^{12}	0.55	0.46	0.43	0.37	0.28
	Wyman, Walter F.	Cousins Island		1279.8	-	-	8119.0	1.33×10^{13}	-	-	-	-	1.33×10^{13}	32.82	10398	6.61×10^{12}	0.79	0.66	0.61	0.53	0.40
	Grahme	Veazie	Penobscot R.	271.8	-	-	545.7	3.44×10^{12}	-	-	-	-	3.44×10^{12}	26.98	12649	1.91×10^{12}	0.23	0.19	0.18	0.15	0.11
	Caribou	Caribou	St. John's River	143.8	-	-	320.3	2.00×10^{12}	-	-	-	-	2.00×10^{12}	24.49	13939	1.16×10^{12}	0.14	0.12	0.11	0.093	0.07
MARYLAND	Smith, R. Paul	Williamsport	Potomac R.	759.7	372.8	8.91×10^{12}	-	-	-	-	-	-	8.91×10^{12}	29.11	11724	4.76×10^{12}	0.57	0.47	0.44	0.38	0.28
	Crane Chas.P.	Baltimore	Seneca Cr. at Tidewater	2210.2	772.1	2.12×10^{13}	-	-	-	-	-	-	2.12×10^{13}	35.56	9598	9.96×10^{12}	1.19	0.99	0.92	0.80	0.60
	Gould St.	Baltimore	Patapsco R.	778.7	321.1	8.6×10^{12}	-	-	55.4	5.68×10^{10}	-	-	8.66×10^{12}	30.70	11118	4.49×10^{12}	0.54	0.48	0.41	0.36	0.27
	Riverside	Baltimore	Patapsco R.	1430.3	611.6	1.64×10^{13}	-	-	-	-	-	-	1.64×10^{13}	29.85	11434	8.61×10^{12}	1.03	0.86	0.79	0.69	0.52
	Wagner, H.A.	Hawkins Point	Patapsco R.	1971.8	703.8	1.91×10^{13}	-	-	-	-	-	-	1.91×10^{13}	35.39	9672	9.00×10^{12}	1.08	0.90	0.83	0.72	0.54
	Westport	Baltimore	Patapsco R.	670.6	342.6	9.22×10^{12}	-	-	-	-	-	-	9.22×10^{12}	24.83	13747	5.32×10^{12}	0.64	0.53	0.49	0.42	0.32
	Vienna	Vienna	Manticoke R.	304.9	171.0	4.41×10^{12}	11.5	6.65×10^{10}	-	-	-	-	4.47×10^{12}	23.27	14666	2.65×10^{12}	0.32	0.26	0.24	0.21	0.16
	Cumberland High Press.	Cumberland	Potomac River	130.9	71.4	1.72×10^{12}	-	-	-	-	-	-	1.72×10^{12}	25.95	13153	9.74×10^{11}	0.12	0.097	0.09	0.078	0.058
MASSA-CHUSETTS	Edgar Sec. I	North Weymouth	-	233.9	15.3	4.14×10^{11}	747.9	4.69×10^{12}	-	-	-	-	5.10×10^{12}	15.64	21818	3.41×10^{12}	0.41	0.34	0.31	0.27	0.20
	Edgar Sec. II	North Weymouth	Boston Bay	1846.4	-	-	2535.6	1.59×10^{13}	3240.2	3.28×10^{12}	-	-	1.91×10^{13}	32.96	10354	9.47×10^{12}	1.13	0.95	0.87	0.76	0.57
	Mystic Sec. I	Everett	Boston Bay	403.2	146.9	4.03×10^{12}	260.0	1.76×10^{12}	-	-	-	-	5.79×10^{12}	23.78	14352	3.40×10^{12}	0.41	0.34	0.31	0.27	0.20
	Mystic Sec. II	Everett	Boston Bay	2777.2	322.4	8.85×10^{12}	2681.2	1.81×10^{13}	-	-	-	-	2.69×10^{13}	35.21	9694	1.97×10^{13}	1.59	1.37	1.17	1.02	0.76
	'L' St.	S. Boston	Boston Bay	425.8	15.2	4.06×10^{11}	1118.4	7.00×10^{12}	-	-	-	-	7.40×10^{12}	19.63	17390	4.66×10^{12}	0.56	0.46	0.43	0.37	0.28
	Mt.Tom	Holyoke	Connecticut River	1133.8	468.1	1.09×10^{13}	-	-	-	-	-	-	1.09×10^{13}	35.57	9597	5.11×10^{12}	0.61	0.51	0.47	0.41	0.31
	Somerset	Somerset	Taunton R.	1520.7	450.9	1.23×10^{13}	1339.0	8.45×10^{12}	-	-	-	-	2.07×10^{13}	29.96	11391	1.09×10^{13}	1.30	1.09	1.00	0.87	0.65
	Brayton Point	Somerset	Taunton R. Tidewater	3822.1	1299.0	3.37×10^{13}	-	-	-	-	-	-	3.37×10^{13}	38.77	8804	1.47×10^{13}	1.76	1.47	1.36	1.17	0.88
	Salem Harbor	Salem	Atlantic Ocean	1888.1	669.3	1.81×10^{13}	20.4	1.28×10^{11}	-	-	-	-	1.82×10^{13}	35.45	9627	8.55×10^{12}	1.02	0.85	0.79	0.68	0.51
	West Springfield	West Springfield	Connecticut River	1404.2	602.4	1.36×10^{13}	-	-	-	-	-	-	1.36×10^{13}	32.78	10411	6.75×10^{12}	0.81	0.67	0.62	0.54	0.40
	Cannon St.	New Bradford	Acushnet R.	635.1	6.3	1.71×10^{11}	815.4	5.13×10^{12}	4127.3	4.13×10^{12}	-	-	9.43×10^{12}	22.99	14843	5.61×10^{12}	0.67	0.56	0.52	0.45	0.34
	W.Water St.	Taunton	Taunton	184.5	-	-	498.4	3.14×10^{12}	-	-	-	-	3.14×10^{12}	20.08	16992	2.00×10^{12}	0.23	0.20	0.18	0.16	0.12
MARYLAND	Chalk Point	Chalk Point	Patuxent R.	3980.3	1182.4	3.12×10^{13}	-	-	-	-	-	-	3.12×10^{13}	39.15	8717	1.35×10^{13}	1.69	1.35	1.25	1.08	0.81
	Dickerson	Dickerson	Potomac River	4001.3	1389.7	3.59×10^{13}	-	-	-	-	-	-	3.59×10^{13}	38.01	8980	1.60×10^{13}	1.91	1.60	1.47	1.28	0.96

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Rej. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	12° F.	13° F.	15° F.	20° F.
MICHIGAN	Campbell, J.R.	W.Olive	Lake Michigan	1953.9	678.1	1.74×10^{13}	-	-	-	-	-	-	1.74×10^{13}	38.35	8900	7.68×10^{12}	0.98	0.77	0.71	0.61	0.46
	Cobb, B.C.	Muskegon	Muskegon L.	2697.6	1105.3	2.69×10^{13}	-	-	-	-	-	-	2.69×10^{13}	34.87	9789	1.86×10^{13}	1.51	1.86	1.16	1.00	0.75
	Karn, Dan H.	Essexville	Saginaw Bay	3952.4	1389.9	3.48×10^{13}	-	-	-	-	-	-	3.48×10^{13}	38.46	8874	1.51×10^{13}	1.80	1.50	1.39	1.80	0.90
	Morrow, Bryce E.	Kalamazoo	Kalamazoo River	584.7	883.8	6.01×10^{12}	-	-	-	-	-	-	6.01×10^{12}	29.82	11447	3.16×10^{12}	0.38	0.32	0.29	0.25	0.19
	Weadock, John C.	Bay City	Saginaw Bay	2706.5	1095.9	2.73×10^{13}	-	-	-	-	-	-	2.73×10^{13}	33.90	10069	1.38×10^{13}	1.59	1.32	1.20	1.06	0.79
	Whiting, J.R.	Erie	Lake Erie	2491.9	1087.8	2.41×10^{13}	-	-	-	-	-	-	2.41×10^{13}	35.84	9685	1.14×10^{13}	1.37	1.14	1.05	0.91	0.68
	Moores Park	Lansing	Grand River	817.1	354.5	9.16×10^{12}	-	-	-	-	-	-	9.16×10^{12}	30.44	11213	4.77×10^{12}	0.57	0.48	0.44	0.38	0.29
	Conner's Creek	Detroit	Detroit River	2219.7	1093.2	2.70×10^{13}	-	-	-	-	-	-	2.70×10^{13}	28.03	12175	1.47×10^{13}	1.76	1.47	1.36	1.17	0.88
	Delray	Detroit	Detroit River	1053.2	510.2	1.38×10^{13}	-	-	-	-	-	-	1.38×10^{13}	26.00	13128	7.81×10^{12}	0.94	0.78	0.72	0.62	0.47
	Marysville	Marysville	St. Clair R.	811.1	480.6	1.08×10^{13}	-	-	-	-	-	-	1.08×10^{13}	27.02	12632	5.69×10^{12}	0.68	0.57	0.52	0.45	0.34
	River Rouge	River Rouge	Detroit River	6158.1	2689.6	5.71×10^{13}	-	-	-	-	-	-	5.71×10^{13}	36.84	9265	9.61×10^{13}	3.18	2.60	2.40	2.08	1.56
	St. Clair	Chim Twp.	Lake St. Clair	9400.9	3589.1	8.69×10^{13}	-	-	-	-	-	-	8.69×10^{13}	37.16	9186	3.98×10^{13}	4.69	3.91	3.61	3.12	2.34
	Trenton Channel	Trenton	Detroit River	2095.4	1000.1	2.59×10^{13}	-	-	-	-	-	-	2.59×10^{13}	27.65	12343	1.48×10^{13}	1.70	1.42	1.31	1.13	0.85
	Historeky	Detroit	Detroit River	588.9	280.8	5.48×10^{12}	-	-	-	-	-	-	5.48×10^{12}	32.68	10445	2.73×10^{12}	0.33	0.27	0.25	0.20	0.16
	Presque Isle	Marquette	Lake Superior	783.4	325.0	8.98×10^{12}	-	-	-	-	-	-	8.98×10^{12}	29.78	11460	4.73×10^{12}	0.57	0.47	0.44	0.38	0.28
	Escanaba	Escanaba	Lake Michigan	107.8	59.1	1.58×10^{12}	-	-	-	-	-	-	1.58×10^{12}	23.36	14613	9.38×10^{11}	0.11	0.093	0.086	0.074	0.056
	Marion, J.H.	L'Anse	Lake Superior	98.2	68.6	1.91×10^{12}	-	-	-	-	-	-	1.91×10^{12}	16.44	20762	1.87×10^{12}	0.15	0.13	0.12	0.10	0.08
	South Haven	South Haven	Lake Michigan	54.1	34.3	9.47×10^{11}	-	-	-	-	-	-	9.47×10^{11}	19.50	17499	5.96×10^{11}	0.07	0.06	0.055	0.045	0.036
	Wyandotte	Wyandotte	BO RECORD	104.8	63.0	1.61×10^{12}	-	-	-	-	-	-	1.61×10^{12}	22.18	15389	9.73×10^{11}	0.12	0.097	0.09	0.078	0.058
MINNESOTA	Aurora	Aurora	Colby Lake	518.7	232.9	5.89×10^{12}	-	-	-	-	-	-	5.89×10^{12}	30.08	11345	3.08×10^{12}	0.37	0.31	0.28	0.25	0.19
	Clay Boswell	Cohasset	Mississippi R.	911.0	369.0	9.19×10^{12}	-	-	-	-	-	-	9.19×10^{12}	33.82	10092	4.48×10^{12}	0.54	0.45	0.41	0.36	0.27
	Ribbard, M.L.	Duluth	Lake Superior	348.3	117.4	3.08×10^{12}	-	-	-	-	-	-	3.08×10^{12}	38.58	8847	1.35×10^{12}	0.16	0.14	0.13	0.11	0.08
	Minnesota Valley	Granite Falls	Minnesota R.	98.6	51.0	1.86×10^{12}	-	-	-	-	-	-	1.86×10^{12}	26.63	12815	7.06×10^{11}	0.085	0.07	0.065	0.056	0.042
	Fox Lake	Sherburn	Fox Lake	478.4	41.6	1.01×10^{12}	-	-	3846.5	3.96×10^{12}	-	-	4.97×10^{12}	38.88	8917	1.89×10^{12}	0.23	0.19	0.17	0.15	0.11
	Crookston	Crookston	Red Lake River	12.5	2.6	3.78×10^{10}	-	-	192.5	2.02×10^{11}	-	-	2.39×10^{11}	17.83	19146	1.55×10^{11}	0.019	0.015	0.014	0.012	0.009
	Hoot Lake	Fergus Falls	Otter Tail R.	696.6	577.6	7.99×10^{12}	-	-	-	-	-	-	7.99×10^{12}	29.75	11471	4.98×10^{12}	0.61	0.49	0.39	0.34	0.25
	Ortonville	Ortonville	Big Stone Lake	38.3	30.0	3.73×10^{11}	-	-	-	-	-	-	3.73×10^{11}	21.33	15999	2.38×10^{11}	0.027	0.023	0.021	0.018	0.014
	Red Wing	Red Wing	Mississippi R.	134.2	83.3	8.55×10^{11}	-	-	1071.1	9.45×10^{11}	-	-	1.80×10^{12}	25.45	13413	1.03×10^{12}	0.12	0.10	0.09	0.08	0.06
	Riverside	Minneapolis	Mississippi R.	1812.6	658.6	1.59×10^{13}	-	-	4070.5	3.99×10^{12}	-	-	1.99×10^{13}	31.14	10961	1.08×10^{13}	1.29	1.02	0.94	0.81	0.61
	Whitney	St. Cloud	Mississippi R.	90.0	10.9	2.89×10^{11}	-	-	517.3	5.80×10^{11}	-	-	8.10×10^{12}	21.08	16194	4.97×10^{11}	0.06	0.05	0.046	0.04	0.03
	Wilmarth	Minneiato	Minnesota R.	99.4	83.5	5.64×10^{11}	-	-	806.0	8.11×10^{11}	-	-	1.38×10^{12}	24.58	13880	7.99×10^{11}	0.096	0.079	0.073	0.063	0.047
	Winona	Winona	Mississippi R.	68.3	45.3	9.9×10^{11}	-	-	-	-	-	-	9.9×10^{11}	23.44	14558	5.87×10^{11}	0.07	0.06	0.05	0.047	0.035
	Black Dog	Minneapolis	Minnesota River	2829.3	699.7	1.60×10^{13}	-	-	1487.0	1.41×10^{13}	-	-	3.01×10^{13}	38.08	10840	1.58×10^{13}	1.88	1.51	1.40	1.21	0.91
	High Bridge	St. Paul	Mississippi R.	2768.0	698.6	1.55×10^{13}	756.2	1.80×10^{10}	1487.4	1.45×10^{13}	-	-	3.00×10^{13}	31.40	10870	1.53×10^{13}	1.84	1.53	1.41	1.22	0.92

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation B-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 Bbls.	BTU OIL	GAS 1,000,000 cu.Ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Effi-ciency Percent	HEAT RATE BTU PER KWH	BTU Rej. To Cooling Water	COOLING WATER REQUIRED - 10^{11} Gals. per Yr. For Temperature Rise 10° F.	12° F.	13° F.	15° F.	20° F.
MISSISSIPPI	Eaton	Hatti-esburg	Leaf River Biloxi	189.2	-	-	-	-	9483.7	9.5×10^{12}	-	-	2.5×10^{12}	30.00	13719	1.46×10^{12}	0.18	0.15	0.14	0.12	0.09
	Jack Watson	Harrison Co.	River	1558.1	-	-	-	-	16868.8	1.6×10^{13}	-	-	1.6×10^{13}	33.18	10287	7.51×10^{12}	0.95	0.79	0.73	0.63	0.47
	Sweatt	Merid-ian	Deep Wells & C.T.	387.1	-	-	-	-	4135.8	4.3×10^{12}	-	-	4.3×10^{12}	25.96	13150	2.43×10^{12}	0.29	0.24	0.22	0.19	0.15
	Delta	Cleve-land	Artifi-cial L.	850.0	-	-	-	-	8599.7	9.0×10^{12}	-	-	9.0×10^{12}	32.24	10585	4.58×10^{12}	0.54	0.45	0.42	0.36	0.27
	Natchez	Natchez	Deep Wells & C.T.	265.7	-	-	-	-	1158.5	1.2×10^{12}	-	-	1.2×10^{12}	26.73	12767	1.75×10^{12}	0.21	0.18	0.16	0.14	0.11
	Rex Brown	Jack-son	Pearl R., L.A.																		
			Deep Wells & C.T.	1786.1	-	-	-	-	18875.6	8.0×10^{13}	-	-	8.0×10^{13}	30.38	11238	1.05×10^{13}	1.25	1.04	0.96	0.83	0.63
MISSOURI	Jim Hill	Camp-bell	Wells & C.T.	342.4	-	-	-	-	3019.1	3.0×10^{12}	-	-	3.0×10^{12}	47.05	18627	1.70×10^{12}	0.20	0.17	0.16	0.14	0.10
	Ber-tham	Kansas City	Mis-souri R.	1610.2	219.8	4.9×10^{12}	-	-	13990.1	1.4×10^{13}	-	-	1.8×10^{13}	29.80	11454	9.7×10^{12}	1.16	0.97	0.89	0.78	0.58
	Hunt-ress	Hunt-ress	Artifi-cial L.	3873.6	1782.9	3.9×10^{13}	-	-	-	-	-	-	3.9×10^{13}	32.98	10348	1.68×10^{13}	2.01	1.67	1.54	1.34	1.00
	Ralph Green	Flame-ent	Well & C.T.	185.6	3.7	8.5×10^{10}	-	-	2258.0	2.8×10^{12}	-	-	2.8×10^{12}	25.96	15549	1.75×10^{12}	0.21	0.17	0.16	0.14	0.11
	Sibley	Sibley	Mis-souri R.	643.6	879.3	6.4×10^{12}	-	-	-	-	38.3	2.3×10^{10}	6.4×10^{12}	30.08	11011	3.18×10^{12}	0.37	0.31	0.29	0.25	0.19
	Montrose	Montrose	Wells & C.T.	188.5	81.8	1.8×10^{12}	-	-	-	-	-	-	1.8×10^{12}	28.30	12063	1.05×10^{12}	0.13	0.11	0.097	0.084	0.063
MONTANA	Frank Bird Lewis & Clark	Bill-ings	Yellow-stone R.	170.0	-	-	-	-	1949.3	2.0×10^{12}	-	-	2.0×10^{12}	25.49	13395	1.32×10^{12}	0.16	0.13	0.12	0.10	0.08
		Sidney	Yellow-stone R.	286.3	895.9	1.8×10^{12}	-	-	15.4	1.5×10^{10}	-	-	3.9×10^{12}	25.03	13636	2.8×10^{12}	0.37	0.29	0.25	0.18	0.13
NEBRASKA	Canaday	Lexing-ton	Irriga-tion Canal	478.4	-	-	-	-	5287.5	5.3×10^{12}	-	-	5.3×10^{12}	33.75	10113	2.36×10^{12}	0.28	0.24	0.20	0.19	0.14
	Bluffs	Scotts Bluff	Deep Wells	185.5	-	-	-	-	2256.0	2.4×10^{12}	-	-	2.4×10^{12}	25.49	13390	1.48×10^{12}	0.17	0.14	0.13	0.11	0.09
	Harold Kramer	Bello-vue	Missouri River	879.5	60.5	1.5×10^{12}	-	-	1964.6	1.9×10^{12}	-	-	3.4×10^{12}	27.49	12449	1.98×10^{12}	0.23	0.19	0.18	0.15	0.12
	Herb Canin	Canin	Canin River	2098.3	344.7	8.4×10^{12}	-	-	14783.4	1.4×10^{13}	-	-	2.3×10^{13}	33.77	10107	1.13×10^{13}	1.35	1.13	1.04	0.90	0.68
NEVADA	Clark	Whitney	Wells & C.T.	688.0	-	-	-	-	6951.6	6.8×10^{12}	-	-	6.8×10^{12}	30.80	11080	3.56×10^{12}	0.43	0.36	0.33	0.28	0.21
	Reid Gardner	Moapa	Wells & River	468.3	179.8	4.5×10^{12}	-	-	-	-	-	-	4.5×10^{12}	34.43	9913	2.82×10^{12}	0.34	0.29	0.26	0.22	0.17
	Sunrise	Las Vegas	Sewage Eff.	488.3	-	-	-	-	3879.7	4.0×10^{12}	-	-	4.0×10^{12}	34.24	9966	2.03×10^{12}	0.24	0.20	0.19	0.16	0.12
	Tracy	Sparks	Truckee River	860.1	-	-	1.3	8.1×10^{9}	3006.3	3.0×10^{12}	-	-	3.0×10^{12}	27.63	12353	1.76×10^{12}	0.21	0.18	0.16	0.14	0.11
NEW HAMPSHIRE	Merri-mack	Bow	Merri-mack R.	730.5	278.1	7.0×10^{12}	-	-	-	-	-	-	7.0×10^{12}	35.30	9669	3.61×10^{12}	0.43	0.36	0.33	0.29	0.22
	Schiller	Ports-mouth	At Tide-water	873.9	78.8	1.9×10^{12}	1207.8	7.9×10^{12}	-	-	-	-	9.9×10^{12}	30.06	11353	5.83×10^{12}	0.69	0.58	0.48	0.49	0.32
MISSOURI	James River	Spring-field	James R. Res'vr.	511.3	36.9	8.5×10^{11}	-	-	4789.7	4.8×10^{12}	-	-	5.6×10^{12}	29.90	11414	3.07×10^{12}	0.37	0.31	0.28	0.25	0.18

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation MW-HRS	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU MW-HR	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10° F.	15° F.	13° F.	15° F.	20° F.
NEW JERSEY	England, B.L.	Beesley's Point	Great Egg Harbor Bay	1973.9	715.1	1.84×10^{13}	29.1	1.68×10^{10}	-	-	-	-	1.84×10^{13}	36.68	9306	8.42×10^{12}	1.01	0.84	0.78	0.67	0.50
	Sayerville	Sayerville	Raritan R.	1898.3	542.4	1.49×10^{13}	-	-	4504.2	4.64×10^{12}	-	-	1.95×10^{13}	33.15	10300	9.65×10^{12}	1.15	0.96	0.89	0.77	0.58
	Werner, H.H.	South Amboy	Raritan R.	498.7	137.8	3.77×10^{12}	310.7	1.97×10^{12}	-	-	-	-	5.74×10^{12}	29.44	11595	3.04×10^{12}	0.36	0.30	0.28	0.24	0.18
	Gilbert	Holland	Delaware R.	662.3	284.3	7.69×10^{12}	-	-	-	-	-	-	7.69×10^{12}	29.40	11610	4.08×10^{12}	0.49	0.41	0.38	0.33	0.25
	Bergen	Ridgefield	Passaic R.	3683.9	931.4	2.44×10^{13}	-	-	9630.9	1.01×10^{13}	-	-	3.45×10^{13}	36.53	9342	1.58×10^{13}	1.89	1.58	1.46	1.26	0.95
	Burlington	Burlington	Delaware	1955.8	314.9	8.33×10^{12}	2043.3	1.30×10^{13}	-	-	-	-	2.14×10^{13}	31.86	10712	1.08×10^{13}	1.30	1.08	1.00	0.86	0.65
	Essex	Newark	Passaic River	729.2	113.0	3.04×10^{12}	944.2	5.95×10^{12}	1364.3	1.42×10^{12}	-	-	1.04×10^{13}	23.90	14278	6.10×10^{12}	0.73	0.61	0.56	0.49	0.37
	Kearny "B"	Kearny	Hackensack R.	1466.0	495.0	1.33×10^{13}	836.1	1.49×10^{12}	-	-	-	-	1.48×10^{13}	33.83	10089	7.20×10^{12}	0.86	0.72	0.66	0.57	0.43
	Hudson	Jersey City	Hackensack R.	2005.9	678.3	1.70×10^{13}	49.2	3.11×10^{11}	-	-	-	-	1.82×10^{13}	37.71	9050	8.13×10^{12}	0.97	0.81	0.75	0.65	0.49
	Marion	Jersey City	Hackensack R.	288.5	-	-	505.3	3.19×10^{12}	-	-	-	-	3.19×10^{12}	23.70	14401	1.88×10^{12}	0.23	0.19	0.17	0.15	0.11
	Mercer	Hamilton Twp.	Delaware River	4181.8	1399.1	3.58×10^{13}	-	-	8005.1	2.10×10^{12}	-	-	3.79×10^{13}	37.68	9058	1.70×10^{13}	2.03	1.70	1.56	1.35	1.02
	Sewaren	Sewaren	Arthur Kill	3776.8	535.0	1.48×10^{13}	3922.8	2.06×10^{13}	4590.3	4.81×10^{12}	-	-	3.96×10^{13}	32.51	10500	1.98×10^{13}	2.37	1.98	1.83	1.58	1.19
	Vineland	Vineland	Wells & C.T.	169.7	97.5	2.71×10^{12}	-	-	-	-	-	-	2.71×10^{12}	21.41	15944	1.65×10^{12}	0.20	0.17	0.15	0.13	0.10
NEW MEXICO	Carlsbad	Carlsbad	Pecos River Wells & C.T.	115.4	-	-	-	-	1606.1	1.61×10^{12}	-	-	1.61×10^{12}	24.52	13918	9.31×10^{11}	0.11	0.093	0.086	0.074	0.056
	Cunningham	Hobbs	Wells & C.T.	1066.5	-	-	-	-	10971.4	1.10×10^{13}	-	-	1.10×10^{13}	33.18	10287	5.41×10^{12}	0.65	0.54	0.50	0.43	0.32
	Lordsburg	Lordsburg	Wells & C.T.	128.6	-	-	-	-	1648.8	1.65×10^{12}	-	-	1.65×10^{12}	25.38	13449	9.48×10^{11}	0.11	0.094	0.087	0.075	0.056
	Person	Albuquerque	Wells & C.T.	377.7	-	-	7.8	4.83×10^{10}	4186.5	4.43×10^{12}	-	-	4.48×10^{12}	27.27	12518	2.47×10^{12}	0.30	0.25	0.23	0.20	0.15
	Reeves	Albuquerque	Wells & C.T.	1089.0	-	-	10.3	6.57×10^{10}	10991.2	1.16×10^{13}	-	-	1.17×10^{13}	31.78	10739	5.93×10^{12}	0.71	0.59	0.55	0.47	0.35
NEW YORK	Danskammer	Roseton	Hudson R.	1790.1	696.0	1.77×10^{13}	-	-	35.7	3.66×10^{10}	-	-	1.77×10^{13}	34.45	9909	8.58×10^{12}	1.09	0.85	0.79	0.68	0.51
	Lovett	Nelson	Hudson R.	669.8	214.9	5.54×10^{12}	-	-	1856.8	1.93×10^{12}	-	-	7.47×10^{12}	30.61	11151	3.68×10^{12}	0.46	0.39	0.36	0.31	0.23
	Arthur Kill	Staten Island	Arthur Kill	1975.5	669.7	1.80×10^{13}	94.2	5.84×10^{11}	-	-	-	-	1.86×10^{13}	36.34	9391	8.56×10^{12}	1.03	0.85	0.79	0.68	0.51
	Astoria	Astoria	East River	6612.5	1916.6	5.89×10^{13}	-	-	12849.7	1.34×10^{13}	-	-	6.63×10^{13}	34.05	10024	3.21×10^{13}	3.84	3.20	2.96	2.56	1.92
	East River	New York	East River	2306.7	783.2	1.95×10^{13}	1994.4	1.25×10^{13}	128.2	1.89×10^{11}	-	-	3.21×10^{13}	24.54	13906	1.86×10^{13}	2.23	1.85	1.71	1.48	1.11
	Hell-Gate	New York	East River	1506.1	-	-	8915.2	1.88×10^{13}	9546.8	9.95×10^{12}	-	-	2.88×10^{13}	18.26	18694	1.81×10^{13}	2.16	1.80	1.67	1.44	1.08
	Hudson	New York	East River	2393.6	897.6	8.06×10^{12}	4583.9	2.86×10^{13}	-	-	-	-	3.67×10^{13}	88.86	1533[illegible]	2.21×10^{13}	2.65	2.21	2.04	1.76	1.32
	Ravenswood	Long Island	East River	5930.7	-	-	6562.5	4.10×10^{13}	16718.1	1.74×10^{13}	-	-	5.84×10^{13}	34.67	9[illegible]	2.79×10^{13}	3.34	2.79	2.57	2.23	1.67
	Shoemaker Creek	New York	Harlem River	645.1	313.0	8.38×10^{12}	-	-	488.6	4.46×10^{11}	-	-	8.83×10^{12}	24.93	13689	5.08×10^{12}	0.61	0.51	0.47	0.41	0.30
	Waterside	New York	East River	2888.6	455.8	1.81×10^{13}	-	-	17830.9	1.80×10^{13}	-	-	3.61×10^{13}	25.85	13200	1.78×10^{13}	2.06	1.71	1.58	1.37	1.03
	Barrett, E.F.	Island Park	Bay Island & Brunswick Is., Canal	2259.4	441.5	1.18×10^{13}	1544.0	9.64×10^{12}	772.3	9.83×10^{11}	-	-	2.18×10^{13}	35.48	9636	1.03×10^{13}	1.23	1.02	0.95	0.80	0.61
	Far Rockaway	Far Rockaway	Bayswater Channel	511.2	-	-	576.8	3.61×10^{12}	1833.7	1.91×10^{12}	-	-	5.52×10^{12}	31.60	10802	2.81×10^{12}	0.34	0.28	0.26	0.23	0.17
	Glenwood	Glenwood Landing	Long Island Sound	1548.5	-	-	738.6	4.61×10^{12}	12969.8	1.29×10^{13}	-	-	1.75×10^{13}	30.21	11300	9.15×10^{12}	1.10	0.91	0.84	0.73	0.55
	Port Jefferson	Port Jefferson	Long Island Sound	2844.3	444.8	1.18×10^{13}	3944.7	1.28×10^{13}	-	-	-	-	2.46×10^{13}	33.95	10052	1.19×10^{13}	1.43	1.19	1.10	0.95	0.71

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	NET Generation MW-HRS	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F.	12°F.	13°F.	15°F.	20°F.
NEW YORK	Gouley	Binghamton	Triughnidgar.	584.3	233.7	5.93×10^{12}	-	-	-	-	-	-	5.93×10^{12}	33.64	10146	2.90×10^{12}	0.35	0.29	0.27	0.23	0.17
	Greenidge	Dresden	Seneca L.	697.7	285.3	7.01×10^{12}	-	-	-	-	-	-	7.01×10^{12}	33.97	10048	3.40×10^{12}	0.41	0.34	0.31	0.27	0.20
	Hickling	E.Corning	Chemung R.	276.1	147.7	3.68×10^{12}	-	-	-	-	-	-	3.68×10^{12}	25.61	13327	2.09×10^{12}	0.25	0.21	0.19	0.17	0.13
	Jamaica	Hainbridge	Susquehanna R.	135.6	76.9	1.91×10^{12}	-	-	-	-	-	-	1.91×10^{12}	24.23	14086	1.11×10^{12}	0.13	0.11	0.10	0.09	0.07
	Milliken	Lake Ridge	Lake Cayuga	2021.8	724.1	1.88×10^{13}	-	-	-	-	-	-	1.88×10^{13}	36.80	9274	8.57×10^{12}	1.03	0.86	0.79	0.68	0.51
	Russel	Rochester	L.Ontario	1562.0	596.7	1.59×10^{13}	-	-	-	-	-	-	1.59×10^{13}	33.60	10158	7.76×10^{12}	0.93	0.77	0.72	0.62	0.46
	Carlson, S.A.	Jamestown	Chadakoin R.	200.0	117.9	3.18×10^{12}	-	-	-	-	-	-	3.18×10^{12}	21.47	15894	1.94×10^{12}	0.23	0.19	0.18	0.16	0.11
	Albany	Albany	Hudson R.	2694.6	960.6	2.56×10^{13}	-	-	-	-	-	-	2.56×10^{13}	35.87	9515	1.20×10^{13}	1.43	1.19	1.10	0.95	0.72
	Dunkirk	Dunkirk	L. Erie	3555.6	1237.7	3.30×10^{13}	-	-	-	-	-	-	3.30×10^{13}	36.75	9287	1.51×10^{13}	1.81	1.51	1.39	1.21	0.90
	Huntley, C.R.	Tonawanda	Niagara R.	4494.5	1594.9	4.30×10^{13}	-	-	-	-	-	-	4.30×10^{13}	35.67	9568	2.01×10^{13}	2.41	2.01	1.85	1.61	1.21
	Oswego	Oswego	L.Ontario	1429.6	572.4	1.55×10^{13}	-	-	-	-	-	-	1.55×10^{13}	31.54	10823	7.89×10^{12}	0.94	0.79	0.73	0.63	0.47
NORTH CAROLINA	Asheville	Skyland	Artificial																		
			L. Powell Creek & Broad R.	1172.7	441.4	1.10×10^{13}	-	-	-	-	-	-	1.10×10^{13}	36.28	9408	5.1×10^{12}	0.61	0.51	0.47	0.41	0.31
	Cape Fear	Moncure	Cape Fear R.	2224.5	831.7	2.15×10^{13}	-	-	-	-	-	-	2.15×10^{13}	35.30	9668	1.02×10^{13}	1.21	1.01	0.94	0.81	0.61
	Lee, H.F.	Goldsboro	Neuse R.& L.	2397.0	866.6	2.29×10^{13}	-	-	-	-	-	-	2.29×10^{13}	35.75	9547	1.07×10^{13}	1.28	1.07	0.99	0.85	0.64
	Sutton, L.V.	Wilmington	Cape Fear R.	1425.7	582.0	1.43×10^{13}	-	-	-	-	-	-	1.43×10^{13}	33.98	10044	6.95×10^{12}	0.83	0.69	0.64	0.55	0.42
	Weatherspoon	Lumberton	Lumber R.	599.0	162.3	4.25×10^{12}	-	-	-	-	-	-	4.25×10^{12}	32.14	10621	3.20×10^{12}	0.38	0.32	0.30	0.26	0.20
	Allen, G. G.	Belmont	Catawba R	7442.5	2833.2	6.8×10^{13}	-	-	-	-	-	-	6.8×10^{13}	37.14	9190	3.10×10^{13}	3.71	3.10	2.86	2.48	1.86
	Buck	Spencer	Yadkin R.	2199.5	847.5	2.20×10^{13}	-	-	-	-	-	-	2.20×10^{13}	34.09	10012	1.07×10^{13}	1.28	1.06	0.98	0.85	0.64
	Cliffside	Cliffside	Broad R.	1099.5	469.0	1.24×10^{13}	-	-	-	-	-	-	1.24×10^{13}	30.26	11281	6.48×10^{12}	0.78	0.65	0.60	0.52	0.39
	Dan River	Draper	Dan R.	1899.8	732.6	1.88×10^{13}	-	-	-	-	-	-	1.88×10^{13}	34.44	9910	9.05×10^{12}	1.08	0.90	0.83	0.72	0.54
	Marshall	Terrell	Catawba R	2205.0	747.3	1.93×10^{13}	-	-	-	-	-	-	1.93×10^{13}	39.02	8746	8.38×10^{12}	1.00	0.84	0.77	0.67	0.50
	Riverbend	Mt. Holley	Catawba R	2967.7	1128.3	2.92×10^{13}	-	-	-	-	-	-	2.92×10^{13}	34.70	9836	1.40×10^{13}	1.67	1.39	1.29	1.11	0.84
NORTH DAKOTA	Beckett	Mandan	Missouri R.	323.6	299.6	4.18×10^{12}	-	-	-	-	-	-	4.18×10^{12}	26.41	12925	2.35×10^{12}	0.28	0.24	0.22	0.19	0.14
	Wood, F. F.	Grand Forks	Red River	23.7	28.9	3.68×10^{11}	-	-	-	-	-	-	3.68×10^{11}	22.00	15516	2.23×10^{11}	0.27	0.22	0.21	0.18	0.13
	Devil's Lake	Devil's Lake	Devil's Lake	27.2	41.8	5.52×10^{11}	-	-	-	-	-	-	5.52×10^{11}	16.81	20298	3.63×10^{11}	0.043	0.036	0.033	0.029	0.022
	Minot	Minot	Souris R.	38.5	62.2	8.40×10^{11}	-	-	-	-	-	-	8.40×10^{11}	15.63	21830	5.62×10^{11}	0.07	0.06	0.05	0.045	0.034
OHIO	Beckjord W.C.	New Richmond	Ohio R.	4566.8	1796.4	4.37×10^{13}	-	-	-	-	-	-	4.37×10^{13}	35.71	9557	2.04×10^{13}	2.44	2.04	1.88	1.63	1.22
	Miami Fort	Columbia Fort	Ohio R.	1789.2	842.2	1.92×10^{13}	-	-	-	-	-	-	1.92×10^{13}	31.90	10700	9.69×10^{12}	1.16	0.97	0.89	0.77	0.58
	West End	Cincinnati	Ohio R.	594.8	335.7	8.57×10^{12}	-	-	-	-	-	-	8.57×10^{12}	23.69	14408	5.04×10^{12}	0.60	0.50	0.46	0.40	0.30
	Ashtabula	Ashtabula	L. Erie	1774.3	789.6	1.89×10^{13}	-	-	-	-	-	-	1.89×10^{13}	32.08	10638	9.52×10^{12}	1.14	0.95	0.88	0.76	0.57
	Avon	Avon Lake Village	L. Erie	2178.2	974.7	2.35×10^{13}	-	-	-	-	-	-	2.35×10^{13}	31.68	10774	1.19×10^{13}	1.43	1.19	1.10	0.95	0.71
	Eastlake	Eastlake	L. Erie	3785.7	1498.5	3.60×10^{13}	-	-	-	-	-	-	3.60×10^{13}	35.36	9651	1.70×10^{13}	2.03	1.69	1.56	1.35	1.01
	Lake Shore	Cleveland	L. Erie	2429.6	1078.4	2.57×10^{13}	-	-	-	-	-	-	2.57×10^{13}	32.21	10595	1.29×10^{13}	1.55	1.29	1.19	1.03	0.77
	Conesville	Conesville	Muskingum R.&C.T.	2732.8	1256.0	2.80×10^{13}	-	-	-	-	-	-	2.80×10^{13}	33.29	10254	1.38×10^{13}	1.65	1.38	1.27	1.10	0.83
	Poston	Athens	Deep Wells & C. T.	964.2	525.9	1.21×10^{13}	-	-	-	-	-	-	1.21×10^{13}	27.30	12500	6.65×10^{12}	0.80	0.66	0.61	0.53	0.40

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU per KWH	BTU Dis. to Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F.	12°F.	13°F.	15°F.	20°F.
OHIO	Hutchings, O.H.	Miamisburg	Miami R.	2103.4	856.7	2.19×10^{13}	-	-	-	-	-	-	2.19×10^{13}	32.78	10431	1.09×10^{13}	1.31	1.09	1.01	0.87	0.65
	Tait, Frank M.	Dayton	Miami R.	2158.4	945.0	2.22×10^{13}	-	-	-	-	-	-	2.22×10^{13}	33.25	10263	1.09×10^{13}	1.31	1.09	1.01	0.87	0.65
	Burger, R.E.	Dilles Bottom	Ohio R.	2702.8	1115.7	2.72×10^{13}	-	-	-	-	-	-	2.72×10^{13}	33.96	10049	1.32×10^{13}	1.58	1.32	1.21	1.05	0.79
	Edgewater	Lorain	L. Erie	545.1	239.5	5.72×10^{12}	-	-	-	-	-	-	5.72×10^{12}	32.53	10492	2.86×10^{12}	0.34	0.29	0.26	0.23	0.17
	Gorge	Akron	Cuyahoga R.	307.4	164.3	3.82×10^{12}	-	-	-	-	-	-	3.82×10^{12}	27.44	12440	2.11×10^{12}	0.25	0.21	0.19	0.17	0.13
	Mad River	Springfield	Mad River	163.4	90.2	2.24×10^{12}	-	-	-	-	-	-	2.24×10^{12}	24.90	13706	1.29×10^{12}	0.15	0.13	0.12	0.10	0.08
	Miles	Miles	Mahoning R.	1105.3	465.7	1.10×10^{13}	-	-	-	-	-	-	1.10×10^{13}	34.20	9979	5.33×10^{12}	0.64	0.53	0.49	0.43	0.32
	Sammis, W.H.	Stratton	Ohio R.	5612.6	2278.8	5.23×10^{13}	-	-	-	-	-	-	5.23×10^{13}	36.64	9314	2.40×10^{13}	2.87	2.39	2.21	1.91	1.43
	Toronto	Toronto	Ohio R.	600.4	348.6	8.05×10^{12}	-	-	-	-	-	-	8.05×10^{12}	25.47	13402	4.59×10^{12}	0.55	0.46	0.43	0.37	0.28
	Muskingum	McConnelsville	Muskingum R.	5713.6	2574.5	5.41×10^{13}	-	-	-	-	-	-	5.41×10^{13}	36.04	9471	2.51×10^{13}	3.01	2.51	2.32	2.01	1.51
	Philo	Philo	Muskingum R.	1521.1	851.2	1.77×10^{13}	-	-	-	-	-	-	1.77×10^{13}	29.32	11640	9.42×10^{12}	1.13	0.94	0.87	0.75	0.56
	Tidd	Brilliant	Ohio R.	1249.1	600.2	1.44×10^{13}	-	-	-	-	-	-	1.44×10^{13}	29.68	11532	7.62×10^{12}	0.91	0.76	0.70	0.61	0.46
	Kyger Creek	Cheshire	Ohio R.	6884.1	2686.7	6.51×10^{13}	-	-	-	-	-	-	6.51×10^{13}	36.09	9458	3.02×10^{13}	3.62	3.02	2.78	2.41	1.81
	Acme	Toledo	Maumee Bay	771.4	351.1	8.76×10^{12}	-	-	-	-	-	-	8.76×10^{12}	30.05	11360	4.60×10^{12}	0.55	0.46	0.42	0.37	0.28
	Bay Shore	Oregon	Maumee Bay	2961.9	1305.1	2.71×10^{13}	-	-	-	-	-	-	2.71×10^{13}	37.26	9159	1.23×10^{13}	1.47	1.23	1.13	0.98	0.73
	Vim St.	Orrville	Wells & C.T.	67.9	46.4	1.04×10^{12}	-	-	38.8	3.88×10^{10}	-	-	1.08×10^{12}	21.35	15911	6.60×10^{11}	0.08	0.07	0.06	0.05	0.04
OKLAHOMA	Arbuckle	Sulphur	Wells & C.T.	233.3	-	-	0.6	4.10×10^{9}	2926.7	3.03×10^{12}	-	-	3.04×10^{12}	26.20	13027	1.71×10^{12}	0.20	0.17	0.16	0.14	0.10
	Horseshoe Lake	Harrah	Canadian River	2566.7	0.13	3.64×10^{9}	0.22	1.31×10^{9}	24915.5	2.58×10^{13}	-	-	2.58×10^{13}	33.90	10068	1.26×10^{13}	1.50	1.25	1.16	1.00	0.75
	Mustang	Oklahoma City	Lake Overholser	2423.0	0.14	3.63×10^{9}	0.35	1.92×10^{8}	24480.5	2.54×10^{13}	-	-	2.54×10^{13}	32.57	10479	1.27×10^{13}	1.52	1.26	1.17	1.01	0.76
	Riverbank	Muskogee	Arkansas R.	1052.0	-	-	-	-	10006.9	1.04×10^{13}	-	-	1.04×10^{13}	34.60	9864	4.97×10^{12}	0.60	0.50	0.46	0.40	0.30
	North-Eastern	Lologah	Verdigris R. Lake & C. T.	1144.8	-	-	-	-	10851.3	1.16×10^{13}	-	-	1.16×10^{13}	33.68	10133	5.65×10^{12}	0.68	0.57	0.52	0.45	0.34
	South-western	Washita	Washita R.&C.T.	734.0	-	-	-	-	8283.8	8.78×10^{12}	-	-	8.78×10^{12}	28.53	11963	4.78×10^{12}	0.57	0.47	0.44	0.38	0.28
	Tulsa	Tulsa	Arkansas R. & C.T.	2481.9	-	-	-	-	24475.6	2.62×10^{13}	-	-	2.62×10^{13}	32.37	10542	1.31×10^{13}	1.57	1.31	1.21	1.05	0.78
	Weleetka	Weleetka	N.Canadian R.	219.5	-	-	-	-	3143.0	3.39×10^{12}	-	-	3.39×10^{12}	22.11	15436	2.05×10^{12}	0.25	0.21	0.19	0.16	0.12
PENNSYLVANIA	Colfax	Springdale	Allegheny R.	821.0	739.3	1.84×10^{13}	-	-	-	-	-	-	1.84×10^{13}	15.19	22462	1.24×10^{13}	1.49	1.24	1.14	0.99	0.75
	Hiram	Hiram	Monongahela R.	3794.8	1675.5	3.99×10^{13}	-	-	-	-	-	-	3.99×10^{13}	32.47	10513	2.00×10^{13}	2.39	1.99	1.84	1.60	1.20
	Phillips, F.B.	S. Heights	Ohio R.	2666.4	1322.0	3.13×10^{13}	-	-	-	-	-	-	3.13×10^{13}	29.04	11751	1.68×10^{13}	2.01	1.67	1.54	1.34	1.00
	Reed, J. H.	Brunot Island	Ohio R.	644.2	421.4	1.10×10^{13}	-	-	-	-	-	-	1.10×10^{13}	20.08	16997	6.88×10^{12}	0.82	0.68	0.63	0.55	0.41
	Crawford	Middletown	Susquehanna R.	211.4	123.9	3.31×10^{12}	5.5	3.19×10^{10}	-	-	-	-	3.34×10^{12}	21.58	15816	2.04×10^{12}	0.24	0.20	0.19	0.16	0.12

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation MW-HR/YR	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU per KWH	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F.	15°F.	13°F.	15°F.	20°F.
PENNSYLVANIA	Portland	Portland	Delaware R.	3142.9	1110.8	2.86×10^{13}	5.7	3.29×10^{10}	-	-	-	-	2.86×10^{13}	37.52	9096	1.29×10^{13}	1.54	1.28	1.18	1.03	0.77
	Titus	Reading	Schuylkill R.	1363.7	523.5	1.38×10^{13}	9.3	5.38×10^{10}	-	-	-	-	1.38×10^{13}	33.64	10146	6.76×10^{12}	0.81	0.67	0.62	0.54	0.41
	Seward	Seward	Conemaugh R.	1312.5	591.6	1.41×10^{13}	-	-	-	-	-	-	1.41×10^{13}	31.86	10714	7.12×10^{12}	0.85	0.71	0.66	0.57	0.43
	Shamrville	Shamrville	Susquehanna R.	4751.1	1771.9	4.53×10^{13}	-	-	-	-	-	-	4.53×10^{13}	35.82	9526	2.11×10^{13}	2.53	2.11	1.95	1.69	1.27
	Warren	Warren	Allegheny R.	499.3	262.3	6.56×10^{12}	-	-	-	-	-	-	6.56×10^{12}	25.99	13131	3.71×10^{12}	0.44	0.37	0.34	0.30	0.22
	New Castle	W. Pittsburgh	Beaver R.	2123.5	970.9	2.26×10^{13}	-	-	-	-	-	-	2.26×10^{13}	32.06	10644	1.14×10^{13}	1.36	1.14	1.05	.91	0.68
	Brunner Island	York	Susquehanna R.	7053.0	1096.2	2.84×10^{13}	-	-	-	-	-	-	2.84×10^{13}	36.75	9288	1.30×10^{13}	1.55	1.30	1.20	1.04	0.78
	Holtwood	Holtwood	Susquehanna R.	512.7	556.5	1.18×10^{13}	-	-	-	-	-	-	1.18×10^{13}	23.44	14558	6.98×10^{12}	0.84	0.70	0.64	0.56	0.42
	Martins Creek	Stroudsburg	Delaware R.	1563.1	670.6	1.73×10^{13}	-	-	-	-	-	-	1.73×10^{13}	30.89	11081	8.95×10^{12}	1.07	0.89	0.82	0.72	0.54
	Stanton	Reading	Susquehanna R.	428.7	315.9	6.31×10^{12}	-	-	-	-	-	-	6.31×10^{12}	23.18	14721	3.78×10^{12}	0.45	0.37	0.35	0.30	0.22
	Sunbury	Scranton Shamokin Dam	C.T. Susquehanna R.	165.4 2733.4	181.1 1445.6	2.22×10^{12} 3.25×10^{13}	-	-	-	-	-	-	2.22×10^{12} 3.25×10^{13}	25.41 28.68	13436 12801	1.27×10^{12} 1.75×10^{13}	0.15 2.10	0.13 1.75	0.12 1.61	0.10 1.40	1.05
	Barbadoes	W. Harrisburg	Schuylkill R.	479.7	205.4	5.55×10^{12}	67.1	4.22×10^{11}	25.9	2.54×10^{10}	-	-	6.00×10^{12}	27.88	12510	3.31×10^{12}	0.40	0.33	0.31	0.26	0.20
	Chester	Chester	Delaware R.	602.6	269.7	7.32×10^{12}	115.9	7.26×10^{11}	11.9	1.17×10^{10}	-	-	8.05×10^{12}	25.54	13365	4.59×10^{12}	0.55	0.46	0.42	0.37	0.28
	Cromby	Phoenixville	Schuylkill R.	2394.5	852.4	2.31×10^{13}	-	-	-	-	-	-	2.31×10^{13}	35.37	9651	1.09×10^{13}	1.30	1.09	1.00	0.87	0.65
	Delaware	Philadelphia	Delaware R.	2074.3	733.3	1.99×10^{13}	108.1	9.47×10^{11}	-	-	-	-	2.09×10^{13}	34.05	10024	1.01×10^{13}	1.21	1.01	0.93	0.80	0.60
	Eddystone	Eddystone	Delaware R.	4981.1	1586.6	4.33×10^{13}	36.6	3.51×10^{11}	-	-	-	-	4.37×10^{13}	38.93	8766	1.98×10^{13}	2.38	1.98	1.75	1.52	1.14
	Richmond	Philadelphia	Schuylkill R.	1688.2	691.7	1.89×10^{13}	496.8	3.09×10^{12}	-	-	-	-	2.18×10^{13}	26.37	12944	1.28×10^{13}	1.46	1.28	1.13	0.98	0.73
	Schuylkill	Philadelphia	Schuylkill R.	1736.0	-	-	2894.4	1.86×10^{13}	-	-	-	-	1.96×10^{13}	31.80	10736	9.45×10^{12}	1.13	0.94	0.87	0.75	0.57
	Southwark	Philadelphia	Delaware R.	1180.9	556.9	1.51×10^{13}	-	-	-	-	-	-	1.51×10^{13}	26.62	12820	8.45×10^{12}	1.01	0.84	0.78	0.68	0.51
	Armstrong	Brookdale	Allegheny R.	2659.4	1128.3	2.65×10^{13}	-	-	-	-	-	-	2.69×10^{13}	34.31	9949	1.28×10^{13}	1.53	1.27	1.17	1.02	0.76
	Allenburg	Allentown	Spring Creek	299.3	173.9	3.62×10^{12}	-	-	-	-	-	-	3.82×10^{12}	26.72	12771	2.17×10^{12}	0.26	0.21	0.20	0.17	0.13
	Springdale	Springdale	Allegheny R.	1621.1	1003.8	2.26×10^{13}	-	-	-	-	-	-	2.26×10^{13}	28.12	12136	1.23×10^{13}	1.47	1.23	1.13	0.98	0.73
	Mitchell	Courtney	Monongahela R.	3011.7	1229.2	3.11×10^{13}	-	-	-	-	-	-	3.11×10^{13}	33.10	10310	1.53×10^{13}	1.84	1.53	1.41	1.22	0.92
RHODE ISLAND	Manchester Street	Providence	Narragansett Bay	575.6	186.4	5.12×10^{12}	275.3	1.69×10^{12}	-	-	-	-	6.81×10^{12}	28.84	11832	3.65×10^{12}	0.44	0.37	0.34	0.29	0.22
	South St.	Providence	Narragansett Bay	618.1	216.2	5.94×10^{12}	385.8	2.12×10^{12}	-	-	-	-	8.05×10^{12}	26.80	13009	4.53×10^{12}	0.54	0.45	0.42	0.36	0.27
SOUTH CAROLINA	Hanahan Kraft	Chappells	Saluda R.	118.2	62.2	1.71×10^{12}	-	-	-	-	-	-	1.71×10^{12}	29.62	14452	1.03×10^{12}	0.12	0.10	0.093	0.08	0.06
	Pinopolis	Moncks Corner	Santee-Cooper R.	280.5	124.6	3.45×10^{12}	-	-	-	-	-	-	3.45×10^{12}	27.75	12301	1.89×10^{12}	0.23	0.19	0.17	0.15	0.11
	Robinson H.B.	Hartsville	Artificial L.	1177.3	439.6	1.13×10^{13}	-	-	-	-	-	-	1.13×10^{13}	35.69	9562	5.27×10^{12}	0.63	0.53	0.49	0.42	0.32
	Bagnal	Charleston	Ashley R.	181.1	-	-	45.5	2.88×10^{11}	2004.4	2.11×10^{12}	-	-	2.40×10^{12}	25.79	13231	1.36×10^{12}	0.16	0.14	0.13	0.11	0.08
	Miles McMeekin	Iva	Lake Murray	1825.4	338.0	8.82×10^{12}	-	-	7830.7	7.81×10^{12}	-	-	1.66×10^{13}	37.31	9149	7.51×10^{12}	0.88	0.75	0.69	0.60	0.45
	Urquhart	Beech Island	Savannah R.	1264.1	285.4	5.73×10^{12}	-	-	6745.1	7.09×10^{12}	-	-	1.28×10^{13}	33.66	10141	6.26×10^{12}	0.75	0.63	0.58	0.50	0.38
	Lee, W.S.	Pelzer	Saluda R.	2558.0	977.6	2.51×10^{13}	-	-	-	-	-	-	2.51×10^{13}	36.85	9258	1.29×10^{13}	1.55	1.29	1.20	0.95	0.72
	Canadys	Canadys	Edisto R.	1536.0	430.5	1.11×10^{13}	-	-	8735.1	2.68×10^{12}	-	-	1.38×10^{13}	38.07	8965	6.19×10^{12}	0.73	0.61	0.56	0.49	0.37

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F.	12°F.	13°F.	15°F	20°F
SOUTH DAKOTA	Ben French	Rapid City	C.T.	94.8	77.2	1.2×10^{12}	-	-	1.5	1.5×10^{9}	-	-	1.25×10^{12}	25.98	13136	7.04×10^{11}	0.08	0.07	0.07	0.06	0.04
	Aberdeen	Aberdeen	Pond & C.T.	18.6	14.9	4.66×10^{11}	-	-	479.2	4.7×10^{11}	-	-	9.44×10^{11}	17.57	19422	6.13×10^{11}	0.08	0.06	0.06	0.05	0.04
	Mitchell	Mitchell	Pond & C.T.	42.5	23.1	4.28×10^{11}	-	-	371.0	3.7×10^{11}	-	-	7.98×10^{11}	18.17	16781	5.14×10^{11}	0.06	0.05	0.05	0.04	0.03
	Lawrence	Sioux Falls	Big Sioux R.	171.5	29.4	7.35×10^{11}	-		1722.0	1.72×10^{12}	-	-	2.46×10^{12}	23.84	14317	1.44×10^{12}	0.17	0.14	0.13	0.12	0.09
TENNESSEE	Johnsonville 'A'	Johnsonville	Tenn. R. & Kentucky L.	1718.0	756.4	1.77×10^{13}	-	-	-	-	-	-	1.77×10^{13}	33.05	10326	6.75×10^{12}	1.05	0.87	0.81	0.70	0.52
	Johnsonville 'B'	Johnsonville	Tenn. R. & Kentucky L.	4161.3	1692.0	3.95×10^{13}	-	-	-	-	-	-	3.95×10^{13}	35.97	9490	1.54×10^{13}	2.20	1.83	1.69	1.47	1.10
	[illegible]	[illegible]	[illegible]ton	4163.0	1446.3	3.4×10^{13}	-	-	-	-	-	-	3.4×10^{13}	35.84	9466	1.65×10^{13}	1.98	1.65	1.52	1.32	0.99
	Nevier	Joliette	[illegible]	[illegible]	1770.0	4.2×10^{13}	-	-	-	-	-	-	4.2×10^{13}	37.00	9216	1.55×10^{13}	2.20	1.91	1.77	1.53	1.15
	Dallas-tan	Kingston	[illegible] Kerl.	[illegible]	622.0	8.59×10^{13}	-	-	-	-	-	-	8.59×10^{13}	35.65	9574	4.03×10^{13}	4.82	4.02	3.71	3.01	2.41
	Kingston	Kingston	[illegible] Kerl.	[illegible]	622.0	8.59×10^{13}	-	-	-	-	-	-	8.59×10^{13}	35.65	9574	4.03×10^{13}	4.82	4.02	3.71	3.01	2.41
	Allen, Thomas H.	Memphis	Mississippi R.	1642.7	449.7	1.08×10^{13}	-	-	4539.2	4.7×10^{12}	-	-	1.54×10^{13}	36.17	9437	7.71×10^{12}	0.86	0.72	0.66	0.58	0.43
TEXAS	Barbe, J.L.	Mission	Rio Grande R.&C.T.	1001.7	-	-	-	-	10355.4	1.08×10^{13}	-	-	1.08×10^{13}	31.68	10772	5.48×10^{12}	0.66	0.55	0.51	0.44	0.33
	Lon Hill	Calallen	City Water & C.T.	1310.4	-	-	-	-	13769.2	1.4×10^{13}	-	-	1.42×10^{13}	31.41	10865	7.27×10^{12}	0.87	0.73	0.67	0.58	0.44
	La Palma	San Benito	Wells & C.T.	148.4	-	-	-	-	2085.7	2.16×10^{12}	-	-	2.18×10^{12}	23.38	14659	1.09×10^{12}	0.13	0.11	0.10	0.09	0.06
	Laredo	Laredo	Rio Grande R.	262.6	-	-	-	-	3253.3	3.3×10^{12}	-	-	3.32×10^{12}	27.01	12637	1.84×10^{12}	0.22	0.18	0.17	0.15	0.11
	Nueces Bay	Corpus Christi	Ship Channel	536.2	-	-	-	-	5527.2	5.6×10^{12}	-	-	5.83×10^{12}	31.56	10875	2.98×10^{12}	0.36	0.30	0.27	0.24	0.18
	Victoria	Victoria	Guadalupe R.	1412.3	-	-	-	-	14958.4	1.5×10^{13}	-	-	1.53×10^{13}	31.41	10866	7.84×10^{12}	0.94	0.78	0.72	0.63	0.47
	Dallas	Dallas	Wells, Spwy Ponds & C.T.	389.0	-	-	-	-	4954.2	4.9×10^{12}	-	-	4.9×10^{12}	26.76	12755	2.77×10^{12}	0.33	0.28	0.26	0.22	0.17
	Mt. Creek	Dallas	Wtn. Spr. L.	987.4	-	-	-	-	9684.5	1.03×10^{13}	-	-	1.03×10^{13}	29.39	11612	5.47×10^{12}	0.66	0.55	0.50	0.44	0.33
	[illegible]	Dallas	[illegible] R. & Artificial L.	[illegible]	-	-	-	-	27860.6	2.8×10^{13}	-	-	2.84×10^{13}	34.32	9944	1.37×10^{13}	1.64	1.36	1.26	1.09	0.82
	Parkdale	E.Dallas	Trinity R. Wells & C. T.	1053.9	-	-	-	-	11532.2	1.2×10^{13}	-	-	1.22×10^{13}	29.58	11538	6.43×10^{12}	0.77	0.64	0.59	0.51	0.39
	Newman	El Paso	Rio Grande R.&C.T.	1089.4	-	-	-	-	10447.5	1.1×10^{13}	-	-	1.12×10^{13}	33.33	10240	5.49×10^{12}	0.66	0.55	0.51	0.44	0.33
	Sabine	Bridge City	Sabine Lake	2021.5	-	-	-	-	19833.4	2.04×10^{13}	-	-	2.04×10^{13}	33.76	10110	9.96×10^{12}	1.19	0.99	0.92	0.80	0.60
	Graham	Graham	Brazos R.& Artificial L.	1213.1	-	-	-	-	11941.7	1.22×10^{13}	-	-	1.22×10^{13}	34.06	10021	5.8×10^{12}	0.71	0.59	0.54	0.47	0.35
	Handley	Fort Worth	Arlington L. & C.T.	2150.5	-	-	-	-	20443.9	2.09×10^{13}	-	-	2.09×10^{13}	35.16	9706	9.88×10^{12}	1.18	0.99	0.91	0.79	0.59
	Morgan Creek	Colorado City	Champion Creek Res'vr.	1991.0	-	-	-	-	20416.8	2.16×10^{13}	-	-	2.16×10^{13}	31.46	10849	1.38×10^{13}	1.52	1.10	1.08	0.88	0.66

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TABLE 11

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWHR	COAL 1000 Tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWHR	BTU Dis. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F.	13°F.	15°F.	20°F.
TEXAS	Permian Basin	Monahans	Wells & C. T.	1148.3	-	-	-	-	10900.5	1.30×10^{13}	-	-	1.30×10^{13}	30.[illegible]	11277	$.7 \times 10^{12}$	0.81	0.62	0.54	0.41
	Collin County	Frisco	Wells & C. T.	628.8	-	-	-	-	993.4	$.75 \times 10^{12}$	-	-	$.7 \times 10^{12}$	31.[illegible]	10[illegible]	3.45×10^{12}	0.41	0.34	0.31	0.26	0.21
	Lake Creek	Riesel	Artificial L.	1910.9	-	-	-	-	181.3.3	1.97×10^{13}	-	-	1.97×10^{13}	33.1[illegible]	10[illegible]	9.7×10^{12}	1.1[illegible]	0.97	0.90	0.7[illegible]	0.58
	River Crest	Talco	Sulphur R.& Res'v	263.9	-	-	-	-	2658.1	3.0×10^{12}	-	-	3.0×10^{12}	29.[illegible]	11437	1.5×10^{12}	0.19	0.1[illegible]	0.15	0.13	0.10
	Stryker Creek	Cherokee County	Angelina R. &Res'v	1389.7	-	-	-	-	13585.0	1.4×10^{13}	-	-	1.4×10^{13}	34.93	10[illegible]5	7.0×10^{12}	0.84	0.70	0.65	0.5[illegible]	0.42
	Valley	Savoy	Artificial L.	1067.1	-	-	-	-	10350.1	1.0×10^{13}	-	-	1.0×10^{13}	34.[illegible]3	9971	5.14×10^{12}	0.[illegible]	0.51	0.47	0.41	0.31
	Concho	San Angelo	L. Nasworthy	453.9	-	-	-	-	4349.5	1.9×10^{12}	-	-	1.9×10^{12}	[illegible].57	10647	1.11×10^{12}	0.13	0.11	0.10	0.09	0.07
	Oak Creek	Bronte	Lake Surface	150.8	-	-	-	-	[illegible].1	$.[illegible] \times 10^{12}$	-	-	$[illegible] \times 10^{12}$	33.77	1010[illegible]	$3.[illegible] \times 10^{11}$	0.39	0.3[illegible]	0.30	0.2[illegible]	0.19
	Neches	Beaumont	Neches R.	3137.4	-	-	-	-	3[illegible]14.	$3.[illegible] \times 10^{13}$	-	-	$3.[illegible] \times 10^{13}$	[illegible].57	11541	$1.[illegible] \times 10^{13}$	[illegible].9	1.91	1.7[illegible]	1.53	1.15
	Paint Creek	Stamford	Artificial L.	572.9	-	-	-	-	5[illegible].1.	$.4 \times 10^{12}$	-	-	$.4 \times 10^{12}$	[illegible].[illegible]	11.79	3.30×10^{12}	0.40	0.34	0.31	0.27	0.20
	Lake Pauline	Quanah	Artificial L.	128.4	-	-	-	-	1499.3	1.5×10^{12}	-	-	1.5×10^{12}	[illegible].[illegible]	13063	9.33×10^{11}	0.11	0.[illegible]	0.[illegible]	0.08	0.06
	Rio Pecos	Girvin	Wells & C. T.	325.4	-	-	-	-	37.4.5	3.7×10^{12}	-	-	3.7×10^{12}	30.01	1137[illegible]	1.34×10^{12}	0.73	0.19	0.18	0.1[illegible]	0.12
	Knox Lee	Cherokee Lake	Cherokee Lake	596.1	-	-	-	-	[illegible]7.8	7.0×10^{12}	-	-	7.0×10^{12}	[illegible].[illegible]	11775	3.73×10^{12}	0.45	0.37	0.35	0.30	0.22
	Lone Star	Dainerfield	Artificial L.	259.8	-	-	-	-	2946.7	3.0×10^{12}	-	-	3.0×10^{12}	[illegible].59	11[illegible]1	$1.[illegible] \times 10^{12}$	0.19	0.1[illegible]	0.15	0.13	1.10
	Wilkes	Jefferson	Artificial L.	1265.7	-	-	-	-	14057.9	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	34.[illegible]	[illegible]9[illegible]	$.07 \times 10^{13}$	0.73	0.61	0.5[illegible]	0.48	0.3[illegible]
	Rio Grande	In New Mexico; N. of El Paso	Wells & C. T.	599.7	-	-	-	-	1531.1	$1.[illegible] \times 10^{12}$	-	-	$.[illegible] \times 10^{12}$	[illegible].[illegible]	12[illegible]	3.7×10^{12}	0.45	0.37	0.34	0.30	0.22
	Sam Bertron	Houston	Ship Channel	5554.[illegible]	-	-	-	-	[illegible]390.9	$5.[illegible] \times 10^{13}$	-	-	$5.[illegible] \times 10^{13}$	34.[illegible]	[illegible]933	$[illegible] \times 10^{13}$	3.10	2.[illegible]5	2.45	2.12	1.59
	Clarke H. O.	Houston	Wells & C. T.	310.4	-	-	-	-	3[illegible]79.[illegible]	$4.[illegible] \times 10^{12}$	-	-	$4.[illegible] \times 10^{12}$	[illegible].[illegible]	13[illegible]	$.[illegible] \times 10^{12}$	0.[illegible]	0.[illegible]	0.[illegible]	0.[illegible]	0.14
	Deep-water	Pasadena	Ship Channel	1175.4	-	-	-	-	11[illegible].4	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	[illegible].[illegible]	[illegible]638	$[illegible] \times 10^{12}$	0.[illegible]	0.6[illegible]	[illegible].58	0.50	0.38
	Greens Bayou	Houston	Wells & C. T.	904.1	-	-	-	-	1[illegible]67.[illegible]	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	[illegible].[illegible]	117[illegible]	$[illegible] \times 10^{12}$	0.[illegible]	0.57	0.53	0.[illegible]	0.34
	Parish W.A.	Richmond	Fresh Water L.	4081.0	-	-	-	-	38100.3	$3.[illegible] \times 10^{13}$	-	-	$3.[illegible] \times 10^{13}$	[illegible].[illegible]	[illegible]75[illegible]	$1.[illegible] \times 10^{13}$	2.[illegible]	1.[illegible]	1.[illegible]	1.[illegible]	1.14
	Webester	Webester	Clear Creek	2469.6	-	-	-	-	[illegible]440.3	$[illegible] \times 10^{13}$	-	-	$[illegible] \times 10^{13}$	[illegible].[illegible]	[illegible]0[illegible]	$[illegible] \times 10^{13}$	1.52	1.[illegible]	1.17	1.01	0.76
	Wharton T.H.	Houston	Deep Wells & C.T.	1606.9	-	-	-	-	19[illegible]6.7	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	[illegible].[illegible]	[illegible]0[illegible]	$[illegible] \times 10^{12}$	0.[illegible]	0.[illegible]	0.74	0.64	0.48
	Leon Creek	San Antonio	Wells & C. T.	542.9	-	-	-	-	[illegible]693.0	$5.[illegible] \times 10^{12}$	-	-	$5.[illegible] \times 10^{12}$	[illegible].[illegible]	[illegible]0[illegible]	$[illegible] \times 10^{12}$	0.37	0.31	0.28	0.24	0.18
	Mission Road	San Antonio	San Antonio R. Wells,Spray Ponds &C.T.	484.0	-	-	-	-	5[illegible]0.6	$5.[illegible] \times 10^{12}$	-	-	$5.[illegible] \times 10^{12}$	[illegible].[illegible]	[illegible].[illegible]	$[illegible] \times 10^{12}$	0.[illegible]	0.27	0.25	0.22	0.16
	Tuttle W.B.	San Antonio	Wells & C.T.	1754.7	-	-	-	-	17[illegible].0	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	[illegible].[illegible]	[illegible]0[illegible]	$[illegible] \times 10^{12}$	1.06	0.90	0.83	0.72	0.54
	Denver City	Denver City	Wells & C.T.	548.1	-	-	-	-	7027.0	7.4×10^{12}	-	-	7.4×10^{12}	[illegible].[illegible]	13[illegible]	$4.[illegible] \times 10^{12}$	0.51	0.43	0.39	0.34	0.26
	East	Amarillo	Spray Pond & C.T.	308.0	-	-	-	-	4[illegible]6.9	$4.[illegible] \times 10^{12}$	-	-	$4.[illegible] \times 10^{12}$	[illegible].[illegible]	13751	$2.[illegible] \times 10^{12}$	0.[illegible]	0.[illegible]	0.23	0.20	0.15
	Moore County	Sunray	Wells & C.T.	402.8	-	-	-	-	4713.[illegible]	$4.[illegible] \times 10^{12}$	-	-	$4.[illegible] \times 10^{12}$	[illegible].57	11[illegible]6	$2.[illegible] \times 10^{12}$	0.31	0.26	0.24	0.21	0.1[illegible]
	Nichols	Amarillo	Sewage Eff. & C. T.	1060.0	-	-	-	-	10[illegible]74.1	$1.[illegible] \times 10^{13}$	-	-	$1.[illegible] \times 10^{13}$	33.57	10168	5.27×10^{12}	0.63	0.53	0.49	0.42	0.32

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TABLE 11

Cooling Water Requirements

State	Name of Plant	Location	Water Supply	Net Generation MW-HRS	Coal 1000 Tons	BTU Coal	Oil 1000 bbls.	BTU Oil	Gas 1,000,000 cu.ft.	BTU Gas	Other Fuel	BTU Fuel	Total BTU	Thermal Efficiency Percent	Heat Rate BTU per KWH	BTU Div. To Cooling Water	COOLING WATER REQUIRED - 10^{11} GALS. per Yr. For Temperature Rises 10°F	12°F.	13°F.	15°F.	20°F.
TEXAS	Plant "Z"	Earth	Wells & C. T.	1478.1	-	-	-	-	17382.8	1.78×10^{13}	-	-	1.78×10^{13}	32.96	10356	8.61×10^{12}	1.03	0.86	0.79	0.69	0.52
	Riverview	Borger	Spray Pond & C.T.	18.2	-	-	-	-	2977.2	3.49×10^{12}	-	-	3.49×10^{12}	21.36	15978	2.13×10^{12}	0.26	0.21	0.20	0.17	0.13
	Tuco	Abernathy	Wells & C. T.	177.9	-	-	-	-	1487.8	1.41×10^{12}	-	-	1.41×10^{12}	23.73	14384	8.47×10^{11}	0.11	0.08	0.07	0.07	0.05
	Eagle Mount.	Fort Worth	Eagle Mountain L.	391.1	-	-	-	-	10443.1	1.07×10^{13}	-	-	1.07×10^{13}	32.76	10768	5.41×10^{12}	0.65	0.54	0.50	0.43	0.32
UTAH	Carbon County Sect.I	Castle Gate	Price R. & C.T.	178.1	94.7	2.13×10^{12}	-	-	-	-	-	-	2.13×10^{12}	26.17	12116	1.16×10^{12}	0.14	0.12	0.11	0.10	0.07
	Carbon County Sect.II	Castle Gate	Price R. & C.T.	554.2	332.4	5.8×10^{12}	-	-	-	-	-	-	5.8×10^{12}	32.30	10565	2.9×10^{12}	0.35	0.29	0.27	0.24	0.18
	Gadsby Sect.I	Salt Lake City	Jordan R. City Water & C. T.	237.6	-	-	320.7	3.35×10^{12}	-	-	-	-	3.35×10^{12}	26.18	14112	1.9×10^{12}	0.23	0.20	0.18	0.16	0.12
	Gadsby Sect.II	Salt Lake City	Jordan R. City Water & C.T.	325.4	-	-	471.2	3.03×10^{12}	734.1	1.87×10^{12}	-	-	3.7×10^{12}	29.69	11497	1.9×10^{12}	0.23	0.20	0.18	0.16	0.12
	Gadsby Sect.III	Salt Lake City	Jordan R. City Water & C.T.	598.5	-	-	582.3	3.75×10^{12}	536.5	2.66×10^{12}	-	-	6.41×10^{12}	31.89	10704	3.2×10^{12}	0.39	0.32	0.30	0.26	0.19
	Provo	Provo	Provo R. & C.T.	29.2	15.3	3.83×10^{11}	-	-	294.0	2.57×10^{11}	-	-	6.40×10^{11}	15.58	21909	4.26×10^{11}	0.05	0.04	0.04	0.03	0.03
VER-MONT	Moran, J. Edward	Burlington	L. Champlain	76.7	43.1	1.18×10^{12}	-	-	-	-	-	-	1.18×10^{12}	22.22	15363	7.1×10^{11}	0.09	0.07	0.07	0.06	0.04
VIR-GINIA	Potomac River	Alexandria	Potomac River	1946.7	708.9	1.98×10^{13}	-	-	-	-	-	-	1.98×10^{13}	33.50	10188	9.72×10^{12}	1.16	0.97	0.90	0.78	0.58
	Riverton	Riverton	Shenandoah R.	117.5	68.9	1.53×10^{12}	-	-	-	-	-	-	1.53×10^{12}	26.21	13021	8.61×10^{11}	0.10	0.09	0.08	0.07	0.05
	Bremo	Bremo Bluff	James R.	1317.9	498.1	1.34×10^{13}	-	-	-	-	-	-	1.34×10^{13}	33.56	10170	6.56×10^{12}	0.79	0.65	0.60	0.52	0.39
	Chesterfield	Chesterfield	James R.	3767.4	1398.4	3.82×10^{13}	-	-	-	-	-	-	3.82×10^{13}	35.63	10147	1.87×10^{13}	2.24	1.86	1.72	1.49	1.12
	Portsmouth	Portsmouth	Elizabeth R.	3335.3	1188.8	3.26×10^{13}	-	-	-	-	-	-	3.26×10^{13}	34.92	9773	1.55×10^{13}	1.86	1.55	1.43	1.24	0.93
	Possum Point	Dumfries	Potomac R.	2503.2	937.0	2.55×10^{13}	-	-	-	-	-	-	2.55×10^{13}	33.51	10186	1.25×10^{13}	1.50	1.25	1.15	1.00	0.75
	Yorktown	Yorktown	York R.	1941.1	479.1	1.29×10^{13}	-	-	-	-	233.0	7.3×10^{10}	2.01×10^{13}	32.96	10354	1.00×10^{13}	2.40	2.01	1.85	1.60	1.21
	Clinch River	Carr	Clinch R. & C. T.	5435.0	1871.7	4.66×10^{13}	-	-	-	-	-	-	4.66×10^{13}	37.61	9074	2.09×10^{13}	2.50	2.09	1.93	1.67	1.25
	Glen Lyn	Glen Lyn	Kan R.	2187.4	650.4	1.73×10^{13}	-	-	-	-	-	-	2.09×10^{13}	35.67	9569	9.80×10^{12}	1.17	0.98	0.90	0.78	0.59
WEST VIR-GINIA	Cabin Creek	Cabin Creek	Kanawha R.	389.5	181.4	4.81×10^{12}	-	-	46.0	3.06×10^{10}	-	-	4.84×10^{12}	28.53	11965	2.52×10^{12}	0.30	0.25	0.23	0.20	0.15
	Kanawha River	Glasgow	Kanawha R.	2330.8	1211.9	3.03×10^{13}	-	-	-	-	-	-	3.03×10^{13}	37.38	9132	1.37×10^{13}	1.64	1.37	1.26	1.09	0.82
	Philip Sporn	Graham	Ohio R.	6955.0	2791.3	6.42×10^{13}	-	-	-	-	-	-	6.42×10^{13}	36.95	9236	2.93×10^{13}	3.50	2.92	2.69	2.33	1.75
	Windsor	Power	Ohio R.	942.5	535.1	1.29×10^{13}	-	-	-	-	-	-	1.29×10^{13}	25.01	13645	7.39×10^{12}	0.89	0.74	0.68	0.59	0.44
	Albright	Albright	Cheat R.	2295.1	1056.9	2.48×10^{13}	-	-	-	-	-	-	2.48×10^{13}	30.16	11318	1.30×10^{13}	1.56	1.30	1.20	1.04	0.78
	Kanawha	Cresapo	Ohio R.	1839.6	728.4	1.74×10^{13}	-	-	-	-	-	-	1.74×10^{13}	36.00	9480	8.11×10^{12}	0.97	0.81	0.75	0.65	0.49
	Riverville	Riverville	Kanawha R.	1095.0	519.4	1.31×10^{13}	-	-	886.5	4.63×10^{11}	-	-	1.36×10^{13}	29.38	12905	7.63×10^{12}	0.91	0.76	0.70	0.61	0.46
	Willow Island	St.Mary's	Ohio R.	1570.6	733.6	1.84×10^{13}	-	-	-	-	-	-	1.84×10^{13}	32.63	10461	8.19×10^{12}	0.98	0.82	0.75	0.65	0.49

TABLE 11

Cooling Water Requirements

STATE	Name of Plant	Location	Water Supply	Net Generation M-KWH	COAL 1000 tons	BTU COAL	OIL 1000 bbls.	BTU OIL	GAS 1,000,000 cu.ft.	BTU GAS	OTHER FUEL	BTU FUEL	TOTAL BTU	Thermal Efficiency Percent	HEAT RATE BTU KWH	BTU Rls. To Cooling Water	COOLING WATER REQUIRED - 10^{12} GALS. per Yr. For Temperature Rises 10°F.	12°F.	13°F.	15°F.	20°F.
WISCONSIN	Bay Front	Ashland	L.Superior	284.5	140.6	3.66×10^{12}	-	-	-	-	-	-	3.66×10^{12}	26.52	12872	2.05×10^{12}	0.25	0.21	0.19	0.17	0.13
	Mount St. Louis	Medford	L. Superior	836.2	207.9	4.96×10^{12}	-	-	4943.6	4.93×10^{12}	-	-	9.89×10^{12}	28.85	11831	5.31×10^{12}	0.64	0.53	0.49	0.43	0.32
	Nemadji	Superior	L. Superior	58.6	32.8	8.13×10^{11}	-	-	-	-	-	-	8.13×10^{11}	22.68	15458	4.91×10^{11}	0.06	0.05	0.05	0.04	0.03
	Winslow	Superior	L. Superior	109.6	19.3	4.99×10^{11}	-	-	1079.0	1.08×10^{12}	-	-	1.58×10^{12}	23.62	14448	9.32×10^{11}	0.11	0.10	0.09	0.08	0.06
	E. Oak Creek	Oak Creek	L. Michigan	2716.8	1089.5	2.63×10^{13}	-	-	-	-	-	-	2.63×10^{13}	35.30	9669	1.84×10^{13}	1.48	1.24	1.14	0.99	0.74
	S. Oak Creek	Oak Creek	L. Michigan	4252.9	1602.2	3.87×10^{13}	-	-	-	-	-	-	3.87×10^{13}	37.49	9103	1.74×10^{13}	2.09	1.74	1.60	1.39	1.04
	French Island	La Crosse	Mississippi R.	96.5	75.9	1.70×10^{12}	-	-	-	-	-	-	1.70×10^{12}	19.40	17590	1.07×10^{12}	0.13	0.11	0.10	0.09	0.06
	Port Washington	Port Washington	L. Michigan	1346.9	586.9	1.47×10^{13}	-	-	-	-	-	-	1.47×10^{13}	31.25	10921	7.54×10^{12}	0.90	0.75	0.69	0.60	0.45
	Rock River	Beloit	Rock R.	138.0	31.5	7.87×10^{11}	-	-	1047.1	1.05×10^{12}	-	-	1.84×10^{12}	25.66	13299	1.04×10^{12}	0.13	0.10	0.10	0.08	0.06
	Edgewater	Sheboygan	L. Michigan	326.5	151.6	3.73×10^{12}	-	-	-	-	-	-	3.73×10^{12}	29.88	11422	1.96×10^{12}	0.24	0.20	0.18	0.16	0.12
	Rock River	Beloit	Rock R.	835.6	344.4	8.30×10^{12}	-	-	-	-	-	-	8.30×10^{12}	34.35	9936	4.00×10^{12}	0.48	0.40	0.37	0.32	0.24
	Nelson Dewey	Cassville	Mississippi R.	1310.2	576.6	1.29×10^{13}	-	-	-	-	-	-	1.29×10^{13}	34.66	9847	6.17×10^{12}	0.74	0.62	0.57	0.49	0.37
	Pulliam	Green Bay	Green Bay	1815.0	731.5	1.86×10^{13}	-	-	-	-	-	-	1.86×10^{13}	33.35	10235	9.13×10^{12}	1.09	0.91	0.84	0.73	0.55
	Weston	Rothschild	Wisconsin R.	612.2	276.4	6.77×10^{12}	-	-	-	-	-	-	6.77×10^{12}	30.85	11062	3.50×10^{12}	0.81	0.68	0.62	0.54	0.41
	Alma	Alma	Mississippi R.	1174.2	569.2	1.33×10^{13}	-	-	-	-	-	-	1.33×10^{13}	30.90	11047	6.69×10^{12}	0.80	0.67	0.62	0.53	0.40
	Stoneman	Cassville	Mississippi R.	213.5	118.0	2.67×10^{12}	-	-	-	-	-	-	2.67×10^{12}	27.34	12483	1.47×10^{12}	0.18	0.15	0.14	0.12	0.09
WYOMING	Dave Johnston	Glenrock	N. Platte R.	1551.8	1165.0	1.74×10^{13}	-	-	-	-	-	-	1.74×10^{13}	30.52	11182	9.08×10^{12}	1.08	0.90	0.83	0.72	0.54
	Naughton	Kemmerer	Hams Fork R.& C.T.	809.4	459.3	8.25×10^{12}	-	-	-	-	-	-	8.25×10^{12}	33.58	10163	4.08×10^{12}	0.48	0.40	0.37	0.32	0.24
	Gouge	Gouge	Wells & C. T.	240.9	218.1	3.68×10^{12}	-	-	-	-	-	-	3.68×10^{12}	29.37	13256	2.21×10^{12}	0.27	0.22	0.20	0.18	0.13
HAWAII	Honolulu Hicks	Honolulu	Honolulu Harbor	518.6	-	-	996.5	6.50×10^{12}	-	-	-	-	6.50×10^{12}	27.25	12526	3.59×10^{12}	0.43	0.36	0.33	0.29	0.22
	Kahe	Honolulu	Pacific Ocean	1052.1	-	-	1569.4	1.03×10^{13}	-	-	-	-	1.03×10^{13}	35.02	9745	4.87×10^{12}	0.58	0.49	0.45	0.39	0.28
	Waiau	Honolulu	Pearl Harbor	699.5	-	-	1203.1	7.84×10^{12}	-	-	-	-	7.84×10^{12}	28.72	11883	4.23×10^{12}	0.50	0.42	0.39	0.34	0.25
	Waiakea	Hilo	Deep Wells	115.3	-	-	273.8	1.76×10^{12}	-	-	-	-	1.76×10^{12}	20.37	15260	1.06×10^{12}	0.13	0.11	0.10	0.09	0.06
	Kahului	Kahului, Maui	Pacific Ocean	113.8	-	-	247.1	1.59×10^{12}	-	-	-	-	1.59×10^{12}	20.43	13972	9.63×10^{11}	0.11	0.09	0.09	0.07	0.06
PUERTO RICO	Palo Seco	Catano	Atlantic Ocean	1619.8	-	-	2525.4	1.59×10^{13}	-	-	-	-	1.59×10^{13}	34.73	9827	7.60×10^{12}	0.91	0.76	0.70	0.61	0.46
	San Juan	Rio Piedras	Atlantic Ocean	635.3	-	-	1332.8	8.54×10^{12}	-	-	-	-	8.54×10^{12}	25.40	13437	4.87×10^{12}	0.58	0.49	0.45	0.39	0.29
	South Coast	Guayanilla	Atlantic Ocean	1179.4	-	-	1936.9	1.26×10^{13}	-	-	-	-	1.26×10^{13}	31.86	10714	6.40×10^{12}	0.77	0.64	0.59	0.51	0.38

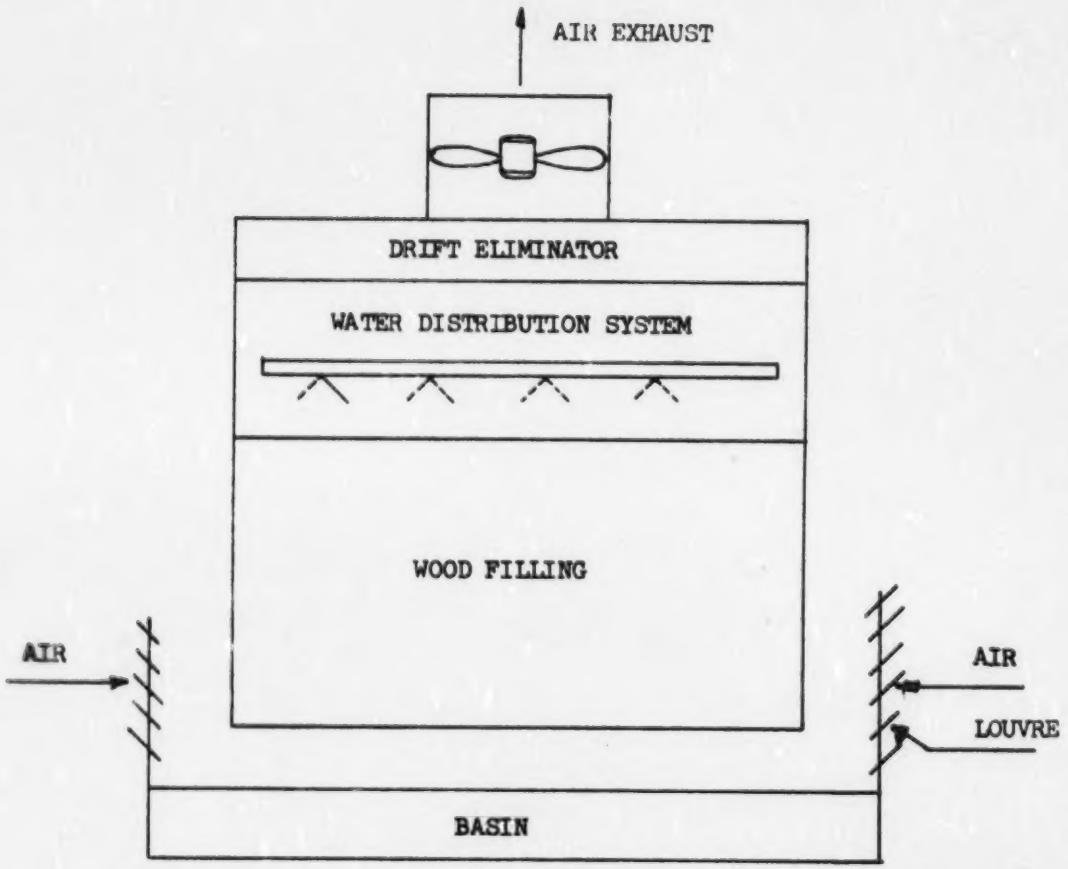

FIGURE 8

COUNTERFLOW INDUCED-DRAFT TOWER

APPENDIX III

COST OF MECHANICAL DRAFT COOLING TOWERS

TABLE 12 AND FIGURE 9

Note: See Section VII for Assumptions and Sample Calculations.

SAMPLE CALCULATION

Name of Plant: Riverton

Plant Location: Riverton, Kansas

Approach Temperature: 10° F.

Approximate Cost of the Tower = $8.00 x (Relative Rating Factor)
x (GPM of Water Used)

RANGE	Cooling Water Required Gals.Year*	GPM	Wet Bulb Temperature**	RRF	Cost $
10° F.	64.0×10^9	12.1×10^4	76° F.	0.85	823,000
15° F.	42.0×10^9	8.07×10^4	76° F.	1.15	743,000
20° F.	32.0×10^9	6.06×10^4	76° F.	1.36	659,000

* From Table 11, Appendix II.

** From "Cooling Towers for Industry" by K. K. McKelvy & Maxey Brooke, 1959.

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Bulb Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
ALABAMA	Barry	79	0.37	0.78	2.31	0.25	1.04	2.06	0.18	1.34	1.84
	Chickasaw	79	0.09	0.78	0.57	0.06	1.04	0.51	0.05	1.34	0.46
	Gadsden	78	0.07	0.80	0.42	0.04	1.08	0.38	0.03	1.38	0.33
	Gorgas	78	0.38	0.80	2.43	0.25	1.08	2.17	0.19	1.38	1.93
	Greene Co.	79	0.09	0.78	0.57	0.06	1.04	0.51	0.05	1.34	0.46
	Gaston, Ernest C.	78	0.78	0.80	5.09	0.52	1.08	4.50	0.40	1.38	4.09
ARIZONA	Cholla	65	0.07	1.13	0.67	0.05	1.60	0.64	0.04	1.90	0.06
	Four Corners	63	0.49	1.93	4.80	0.33	1.68	4.40	0.24	2.09	3.94
	Ocotillo	75	0.05	0.98	0.38	0.04	1.19	0.35	0.03	1.40	0.30
	Saguaro	75	0.04	0.88	0.27	0.03	1.19	0.26	0.02	1.40	0.24
	Agua Fria	75	0.13	0.98	0.94	0.09	1.19	0.86	0.07	1.40	0.75
	Kyrene	75	0.03	0.88	0.22	0.02	1.19	0.20	0.02	1.40	0.18
	De Moss Petrie	70	0.02	1.00	0.19	0.02	1.30	0.16	0.01	1.69	0.15
	Irvington	70	0.13	1.00	1.05	0.09	1.30	0.91	0.06	1.69	0.84
ARKANSAS	Harvey Couch	79	0.11	0.78	0.67	0.07	1.04	0.60	0.05	1.34	0.53
	Cecil Lynch	79	0.18	0.78	1.13	0.12	1.04	1.00	0.09	1.34	0.91
	Lake Catherine	79	0.13	0.78	0.81	0.09	1.04	0.72	0.06	1.34	0.65
	Hamilton Moses	79	0.07	0.78	0.45	0.05	1.04	0.42	0.04	1.34	0.36
	Robt. Ritchie	79	0.93	0.78	1.41	0.15	1.04	1.26	0.12	1.34	1.14
	Jonesboro	79	0.02	0.78	0.10	0.01	1.04	0.082	0.01	1.34	0.07
CALIFORNIA	Magnolia Blvd.	66	-	1.10	-	-	1.54	-	-	1.84	-
	Olive Ave.	66	0.08	1.10	0.78	0.06	1.54	0.71	0.04	1.84	0.69
	Glendale	66	0.06	1.10	0.54	0.04	1.54	0.50	0.03	1.84	0.45
	Broadway Glenarm	66	0.08	1.10	0.69	0.05	1.54	0.63	0.04	1.84	0.56
	Harbor	63	0.19	1.93	1.90	0.13	1.68	1.74	0.10	2.09	1.57
	Haynes	66	0.43	1.10	3.77	0.29	1.54	3.50	0.21	1.84	3.14
	Scattergood	66	0.23	1.10	1.98	0.15	1.54	1.86	0.11	1.84	1.66
	Valley	66	0.30	1.10	2.63	0.20	1.54	2.47	0.15	1.84	2.22
	Contra Costa	71	0.52	0.98	4.10	0.35	1.28	3.57	0.26	1.58	3.30
	Humboldt Bay	63	0.03	1.23	0.27	0.02	1.68	0.26	0.01	2.09	0.22
	Hunter's Point	63	0.27	1.23	2.66	0.18	1.68	2.43	0.14	2.09	2.19
	Kern	64	0.04	1.18	0.36	0.03	1.64	0.33	0.02	1.96	0.30
ALASKA	Widow's Cr."A"	77	0.25	0.83	1.69	0.17	1.11	1.51	0.13	1.38	1.35
	Widow's Cr."B"	77	0.45	0.83	3.00	0.30	1.11	2.69	0.23	1.38	2.40
	Colbert "A"	76	0.44	0.80	2.84	0.29	1.08	2.55	0.22	1.38	2.26

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Bulb Temperature of	RANGE 10° F.			RANGE 15° F.			RANGE 20° F.		
			Cooling Water M/GPM	Relative Rating Factor	Cost, Tower Million Dollars	Cooling Water M/GPM	Relative Water M/GPM	Cost, Tower Million Dollars	Cooling Water M/GPM	Relative Water M/GPM	Cost, Tower Million Dollars
CALIFORNIA	Morro Bay	63	0.36	1.25	3.58	0.24	1.68	3.05	0.18	2.00	2.95
	Moss Landing	63	0.20	1.25	2.01	0.14	1.68	1.85	0.10	2.00	1.67
	Pittsburg	70	0.60	1.00	4.81	0.40	1.30	4.18	0.30	1.60	3.90
	El Centro	80	0.02	0.75	0.18	0.02	1.00	0.13	0.01	1.20	0.11
	Encina	68	0.15	1.05	1.25	0.10	1.42	1.13	0.07	1.73	1.03
	South Bay	70	0.27	1.00	2.20	0.18	1.30	1.90	0.14	1.60	1.78
	Alamitos	70	0.57	1.00	4.57	0.38	1.30	3.96	0.29	1.60	3.70
	Cool Water	66	0.09	1.10	0.77	0.06	1.54	0.73	0.04	1.84	0.65
	El Segundo	63	0.58	1.25	5.70	0.39	1.68	5.20	0.29	2.07	4.68
	Etiwanda	66	0.59	1.10	5.22	0.39	1.54	4.86	0.30	1.84	4.38
	Huntington Beach	66	0.48	1.10	4.26	0.32	1.54	4.00	0.24	1.84	3.56
	Hyperion Beach	66	0.24	1.10	2.13	0.16	1.54	2.00	0.12	1.84	1.82
	Redondo Beach	66	0.23	1.10	2.03	0.15	1.54	1.90	0.11	1.84	1.69
	San Bernardino	66	0.08	1.10	0.67	0.05	1.54	0.64	0.04	1.84	0.57
COLORADO	Arapahoe	63	0.11	1.25	1.10	0.07	1.68	1.00	0.06	2.00	0.90
	Cameo	63	0.05	1.25	0.45	0.30	1.68	0.41	0.02	2.00	0.37
	Cherokee	63	0.28	1.25	2.72	0.19	1.68	2.49	0.14	2.00	2.25
	Valmont	62	0.11	1.28	1.13	0.07	1.78	0.11	0.06	2.08	0.99
	Zuni	63	0.11	1.25	1.09	0.07	1.68	1.00	0.06	2.00	0.90
	Jim Bullock	65	0.02	1.13	0.14	0.01	1.60	0.14	0.08	1.90	0.12
	Devon	74	0.38	0.90	2.72	0.25	1.31	2.42	0.19	1.44	2.20
CONNECTICUT	Montville	75	0.13	0.88	0.92	0.09	1.19	0.82	0.07	1.40	0.73
	Norwalk Harbor	75	0.24	0.88	1.69	0.16	1.19	1.53	0.12	1.40	1.35
	Middletown	74	0.27	0.90	1.95	0.18	1.31	1.75	0.14	1.44	1.56
	S. Meadow	74	0.11	0.90	0.79	0.07	1.31	0.70	0.05	1.44	0.63
	Bridgeport Harbor	75	0.18	0.88	1.25	0.12	1.19	1.13	0.09	1.40	0.99
	English	75	0.09	0.88	0.65	0.06	1.19	0.58	0.05	1.40	0.52
	Steel Point	75	0.08	0.88	0.57	0.05	1.19	0.51	0.04	1.40	0.45

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Bulb Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
DELAWARE	Edge Moor	78	0.15	0.80	0.97	0.1	1.08	0.88	0.08	1.28	0.78
	Indian River	78	0 11	0.80	0.71	0.07	1.08	0.63	0.06	1.28	0.57
D.C.	Benning	78	0.78	0.80	5.50	0.05	1.08	0.45	0.04	1.28	0.41
	Buzzards' Pt.	78	0.03	0.80	0.18	0.02	1.08	0.16	0.01	1.28	0.14
FLORIDA	Cape Kennedy	79	0.16	0.78	1.00	0.11	1.04	0.89	0.08	1.24	0.80
	Ft. Meyers	79	0.05	0.78	0.34	0.04	1.04	0.31	0.03	1.24	0.27
	Lauderdale	79	0.09	0.78	0.56	0.06	1.04	0.50	0.04	1.24	0.44
	Palatka	79	0.006	0.78	0.04	0.003	1.04	0.04	0.003	1.24	0.03
	Cutler	79	0.16	0.78	0.98	0.11	1.04	0.88	0.08	1.24	0.78
	Pt. Everglades	79	0.57	0.78	3.56	0.38	1.04	3.17	0.29	1.24	2.84
	Riviera	79	0.30	0.78	1.86	0.20	1.04	1.66	0.15	1.24	1.50
	Sanford	79	0.07	0.78	0.46	0.05	1.04	0.40	0.04	1.24	0.36
	Crist	79	0.15	0.78	0.93	0.01	1.04	0.83	0.07	1.24	0.74
	Scholz	79	0.08	0.78	0.55	0.03	1.04	0.73	0.07	1.24	0.71
	Lansing Smith	79	0.06	0.78	0.35	0.04	1.04	0.31	0.03	1.24	0.27
	Gannon, P. J.	79	0.40	0.78	2.49	0.26	1.04	2.21	0.20	1.24	1.97
	Hoosers' Pt.	79	0.10	0.78	0.65	0.07	1.04	0.57	0.05	1.24	0.51
	Kennedy, J. D.	79	0.15	0.78	0.95	0.10	1.04	0.86	0.08	1.24	0.76
	Southside	79	0.15	0.78	0.97	0.10	1.04	0.86	0.08	1.24	0.78
	Ft. Pierce	79	0.02	0.78	0.14	0.01	1.04	0.12	0.01	1.24	0.11
	Key West	79	0.03	0.78	0.21	0.02	1.04	0.18	0.02	1.24	0.16
	Indian R.	79	0.12	0.78	0.78	0.08	1.04	0.69	0.06	1.24	0.63
	St. Marks	79	0.06	0.78	0.35	0.04	1.04	0.31	0.03	1.24	0.27
	Avon Park	79	0.03	0.78	0.17	0.02	1.04	0.16	0.01	1.24	0.14
	Bartow, P.L.	79	0.26	0.78	1.62	0.17	1.04	1.45	0.13	1.24	1.29
	Bayboro	79	0.03	0.78	0.22	0.02	1.04	0.19	0.02	1.24	0.17
	Higgins	79	0.08	0.78	0.50	0.05	1.04	0.45	0.04	1.24	0.40
	Suwanee	79	0.07	0.78	0.46	0.05	1.04	0.42	0.04	1.24	0.36
	Turner, G. E.	79	0.14	0.78	0.84	0.09	1.04	0.73	0.07	1.24	0.67
GEORGIA	Arkwright	78	0.10	0.80	0.67	0.07	1.08	0.60	0.05	1.28	0.53
	Atkinson	77	0.12	0.83	0.83	0.08	1.11	0.73	0.07	1.32	0.67
	Br. Harlee	77	0.10	0.83	0.65	0.06	1.11	0.58	0.05	1.32	0.53
	Hammond	77	0.17	0.83	1.15	0.12	1.11	1.04	0.09	1.32	0.93
	McDonough, Jack	77	0.36	0.83	2.38	0.24	1.11	2.13	0.18	1.32	1.89
	McManus	79	0.08	0.78	0.50	0.05	1.04	0.45	0.04	1.24	0.40
	Mitchell	79	0.09	0.78	0.56	0.06	1.04	0.51	0.05	1.24	0.46
	Yates	78	0.33	0.80	2.14	0.23	1.08	1.93	0.17	1.28	1.71
	Pt. Wentworth	79	0.01	0.78	0.62	0.07	1.04	0.56	0.05	1.24	0.50

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
INDIANA	Pritchard, H. J.	76	0.20	0.85	1.35	0.13	1.15	1.21	0.10	1.36	1.08
	Stout, E. W.	76	0.18	0.85	1.25	0.12	1.15	1.13	0.09	1.36	1.00
	Dresser	76	0.07	0.85	0.52	0.05	1.15	0.46	0.04	1.36	0.41
	Edwardsport	77	0.10	0.83	0.67	0.07	1.11	0.60	0.05	1.32	0.53
	Gallagher	76	0.43	0.85	2.94	0.28	1.15	2.65	0.22	1.36	2.36
	Wabash River	76	0.34	0.85	2.33	0.23	1.15	2.11	0.17	1.36	1.87
	Culley, F. B.	78	0.03	0.80	0.22	0.02	1.08	0.20	0.02	1.28	0.18
	Ohio River	78	0.07	0.80	0.44	0.05	1.08	0.40	0.03	1.28	0.36
	Whitewater Valley	76	0.03	0.85	0.20	0.02	1.15	0.18	0.02	1.36	0.17
IOWA	Kapp, Milton	76	0.02	0.85	0.16	0.02	1.15	0.14	0.10	1.36	0.13
	Dubuque	76	0.08	0.85	0.56	0.06	1.15	0.51	0.04	1.36	0.46
	Riverside	76	0.21	0.85	1.40	0.14	1.15	1.27	0.10	1.36	1.12
	Council Bluff	75	0.10	0.88	0.67	0.06	1.19	0.60	0.05	1.40	0.54
	Des Moines, #2	76	0.21	0.85	1.40	0.14	1.15	1.28	0.10	1.36	1.12
	Maynard St.	76	0.06	0.85	0.41	0.04	1.15	0.37	0.03	1.36	0.32
	Reel	76	0.08	0.85	0.56	0.06	1.15	0.51	0.04	1.36	0.46
	Bridgeport	76	0.07	0.85	0.50	0.05	1.15	0.44	0.04	1.36	0.40
	Muscatine	76	0.04	0.85	0.29	0.03	1.15	0.25	0.02	1.36	0.23
	Lansing	76	0.05	0.85	0.35	0.03	1.15	0.32	0.03	1.36	0.29
	Prairie Cr.	76	0.07	0.85	0.46	0.05	1.15	0.42	0.03	1.36	0.38
	Sutherland	76	0.12	0.85	0.79	0.08	1.15	0.72	0.06	1.36	0.65
KANSAS	Colby, No. 2	71	0.01	0.98	0.09	0.008	1.28	0.08	0.006	1.58	0.08
	Ross Beach	73	0.01	0.93	0.08	0.007	1.23	0.07	0.005	1.49	0.06
	Riverton	76	0.12	0.85	0.83	0.08	1.15	0.74	0.06	1.36	0.67
	Riverton	76	0.02	0.85	0.15	0.01	1.15	0.13	0.01	1.36	0.11
	Gordon, Evans	75	0.11	0.88	0.78	0.07	1.19	0.71	0.06	1.40	0.64
	Murray, Gills	75	0.24	0.88	1.69	0.16	1.19	1.53	0.12	1.40	1.35
	Neosho	76	0.03	0.85	0.22	0.02	1.15	0.20	0.01	1.36	0.17
	Ripley	75	0.03	0.88	0.22	0.02	1.19	0.20	0.01	1.40	0.17
	Hutchinson, #2	74	0.10	0.90	0.76	0.07	1.21	0.69	0.05	1.44	0.62
	Lawrence	76	0.12	0.85	0.79	0.08	1.15	0.70	0.06	1.36	0.63
	Riverside	75	0.01	0.88	0.09	0.008	1.19	0.08	0.006	1.40	0.07
	Tecumseh	75	0.17	0.88	1.18	0.11	1.19	1.07	0.08	1.40	0.94
	Ft. Dodge	72	0.03	0.95	0.22	0.02	1.26	0.20	0.01	1.53	0.17
	Cimarron R.	71	0.04	0.98	0.35	0.03	1.28	0.30	0.02	1.58	0.29
	Arthur, Mullergren	74	0.07	0.90	0.51	0.05	1.21	0.47	0.04	1.44	0.42

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

State	Name of Plant	Wet Temperature °F	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
KANSAS	Kaw River	76	0.10	0.85	0.69	0.07	1.15	0.60	0.05	1.36	0.54
	Quindaro	76	0.07	0.85	0.50	0.05	1.15	0.44	0.04	1.36	0.40
	No. 2		N O D A T A A V A I L A B L E								
KENTUCKY	Big Sandy	76	0.20	0.85	1.34	0.13	1.15	1.21	0.10	1.36	1.08
	Brown, E. H.	77	0.12	0.83	0.79	0.08	1.11	0.70	0.06	1.32	0.63
	Green River	77	0.12	0.83	0.81	0.08	1.11	0.73	0.06	1.32	0.65
	Cane Run	77	0.35	0.83	2.32	0.23	1.11	2.07	0.18	1.32	1.85
	Paddy's Run	77	0.10	0.83	0.65	0.06	1.11	0.58	0.05	1.32	0.53
	Paradise	78	0.70	0.80	4.51	0.47	1.08	4.07	0.35	1.28	3.61
	Shawnee	78	1.08	0.80	6.90	0.72	1.08	6.20	0.54	1.28	5.50
LOUISIANA	Willow Green	80	0.25	0.75	1.50	0.17	1.00	1.36	0.13	1.20	1.23
	Little Gypsy	80	0.16	0.75	0.99	0.11	1.00	0.87	0.08	1.20	0.79
	Coughlin	80	0.13	0.75	0.76	0.08	1.00	0.67	0.06	1.20	0.61
	Teche	80	0.05	0.75	0.30	0.03	1.00	0.26	0.02	1.20	0.24
	Louisiana Sta. #2	80	0.10	0.75	0.69	0.07	1.00	0.55	0.05	1.20	0.50
	Nelson, Roy H.	80	0.20	0.75	1.23	0.14	1.00	1.10	0.10	1.20	0.99
	Nine Mile Pt.	80	0.23	0.75	1.39	0.15	1.00	1.24	0.11	1.20	1.10
	Sterlington	80	0.22	0.75	1.33	0.15	1.00	1.18	0.11	1.20	1.06
	Market St.	80	0.06	0.75	0.36	0.04	1.00	0.32	0.03	1.20	0.30
	Richard	80	0.21	0.75	1.24	0.14	1.00	1.10	0.10	1.20	0.99
	Patterson, A. B.	80	0.09	0.75	0.52	0.06	1.00	0.46	0.04	1.20	0.42
	Lieberman	79	0.14	0.78	0.90	0.10	1.04	0.80	0.07	1.24	0.70
MAINE	Mason	71	0.10	0.98	0.83	0.07	1.28	0.73	0.05	1.58	0.68
	Wyman, Walter F.	71	0.15	0.98	1.18	0.10	1.28	1.04	0.08	1.58	0.97
	Graham	70	0.04	1.00	0.35	0.03	1.30	0.30	0.02	1.60	0.28
	Caribou	69	0.03	1.03	0.29	0.02	1.36	0.20	0.01	1.68	0.18
	Smith, E. Paul	75	0.11	0.88	0.77	0.07	1.19	0.69	0.53	1.40	0.60
MARYLAND	Crane, Chas. F.	78	0.23	0.80	1.45	0.15	1.08	1.32	0.11	1.38	1.17
	Gould St.	78	0.10	0.80	0.66	0.07	1.08	0.60	0.05	1.38	0.53
	Riverside	78	0.20	0.80	1.26	0.13	1.08	1.14	0.10	1.38	1.05
	Wagner, H. A.	78	0.21	0.80	1.32	0.14	1.08	1.19	0.10	1.38	1.06
	Westport	78	0.12	0.80	0.78	0.08	1.08	0.70	0.06	1.38	0.63
	Vienna	78	0.06	0.80	0.39	0.04	1.08	0.35	0.03	1.38	0.31
	Cumberland High Pressure	77	0.09	0.95	0.18	0.01	1.26	0.15	0.01	1.53	0.14
	Chalk Point	78	0.31	0.80	1.98	0.21	1.08	1.78	0.16	1.38	1.58
	Dickerson	77	0.36	0.83	2.47	0.24	1.11	2.17	0.18	1.32	1.93

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

State	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
MASS.	Edgar, Sec. I	72	0.08	0.95	0.60	0.05	1.26	0.52	0.04	1.53	0.47
	Edgar, Sec. II	72	0.21	0.95	1.64	0.15	1.26	1.46	0.11	1.53	1.33
	Mystic, Sec. I	72	0.08	0.95	0.60	0.05	1.26	0.52	0.38	1.53	0.47
	Mystic, Sec. II	72	0.29	0.95	2.20	0.19	1.26	1.96	0.14	1.53	1.77
	"L" St.	72	0.11	0.95	0.81	0.07	1.26	0.71	0.05	1.53	0.66
	Mt. Tom	73	0.12	0.93	0.87	0.08	1.23	0.77	0.06	1.49	0.71
	Somerset	74	0.25	0.90	1.79	0.17	1.21	1.61	0.12	1.44	1.43
	Brayton Point	74	0.33	0.90	2.42	0.22	1.21	2.16	0.17	1.44	1.93
	Salem Harbor	72	0.19	0.95	1.48	0.13	1.26	1.31	0.10	1.53	1.19
	W. Springfield	73	0.15	0.93	1.15	0.10	1.23	1.02	0.08	1.49	0.91
	Canton St.	74	0.13	0.90	0.92	0.09	1.21	0.83	0.06	1.44	0.75
	W. Water St.	74	0.04	0.90	0.32	0.03	1.21	0.30	0.02	1.44	0.27
MICHIGAN	Campbell, J. H.	73	0.18	0.93	1.31	0.12	1.23	1.15	0.09	1.44	1.00
	Cobb, B. C.	73	0.29	0.93	2.14	0.19	1.23	1.88	0.14	1.44	1.65
	Dove, Dan E.	71	0.34	0.98	2.69	0.23	1.28	2.34	0.17	1.58	2.17
	Harrow, Bryce E.	73	0.07	0.93	0.54	0.05	1.23	0.47	0.04	1.44	0.41
	Woodcock, John C.	72	0.30	0.95	2.30	0.20	1.26	2.04	0.15	1.53	1.84
	Whiting, J. H.	72	0.26	0.95	1.99	0.17	1.26	1.75	0.13	1.53	1.59
	Monroe Port	72	0.11	0.95	0.83	0.07	1.26	0.73	0.06	1.53	0.68
	Conner's Creek	72	0.33	0.95	2.55	0.22	1.26	2.25	0.17	1.53	2.05
	Delray	72	0.18	0.95	1.36	0.12	1.26	1.19	0.09	1.53	1.10
	Marysville	72	0.13	0.95	0.99	0.09	1.26	0.87	0.06	1.53	0.80
	River Rouge	72	0.59	0.95	4.52	0.40	1.26	3.99	0.30	1.53	3.63
	St. Clair	72	0.89	0.95	6.79	0.59	1.26	5.99	0.45	1.53	5.45
	Trenton Channel	72	0.32	0.95	2.46	0.21	1.26	2.17	0.16	1.53	1.98
	Waterway	70	0.06	1.00	0.51	0.04	1.30	0.44	0.03	1.60	0.40
	Presque Isle	70	0.11	1.00	0.87	0.07	1.30	0.76	0.05	1.60	0.70
	Boesbeck	70	0.02	1.00	0.17	0.02	1.30	0.15	0.01	1.60	0.14
	Harbor, J. H.	70	0.03	1.00	0.23	0.02	1.30	0.20	0.02	1.60	0.20
	S. Haven	73	0.01	0.93	0.10	0.009	1.23	0.09	0.007	1.49	0.08
	Wyandotte	72	0.02	0.95	0.18	0.02	1.26	0.15	0.01	1.53	0.14

Capital Cost of Mechanical Draft Cooling Towers

State	Name of Plant	Wet Temperature oF	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
MINNESOTA	Aurora	70	0.07	1.00	0.57	0.05	1.30	0.50	0.04	1.62	0.47
	Clay Boswell	70	0.10	1.00	0.83	0.07	1.30	0.72	0.05	1.62	0.67
	Hibbard, M. L.	70	0.03	1.00	0.25	0.02	1.30	0.22	0.02	1.62	0.20
	Minnesota Valley	73	0.02	0.93	0.12	0.01	1.23	0.11	0.008	1.49	0.10
	Crookston	69	0.004	1.03	0.03	0.002	1.36	0.02	0.002	1.68	0.03
	Knut Lake	71	0.10	0.98	0.77	0.06	1.28	0.67	0.05	1.58	0.61
	Ortonville	71	0.005	0.98	0.04	0.003	1.28	0.04	0.003	1.58	0.04
	Red Wing	74	0.02	0.90	0.17	0.02	1.21	0.15	0.01	1.44	0.14
	Riverside	73	0.23	0.93	1.73	0.15	1.23	1.52	0.12	1.49	1.39
	Whitney	72	0.01	0.95	0.09	0.008	1.26	0.08	0.006	1.53	0.07
	Wilmarth	75	0.02	0.88	0.13	0.01	1.19	0.12	0.009	1.40	0.10
	Winona	75	0.01	0.88	0.09	0.009	1.19	0.09	0.007	1.40	0.08
	Fox Lake	75	0.04	0.88	0.31	0.03	1.19	0.28	0.02	1.40	0.24
	Black Dog	73	0.35	0.93	2.58	0.25	1.23	2.27	0.17	1.49	2.07
	High Bridge	73	0.35	0.93	2.61	0.23	1.23	2.28	0.18	1.49	2.09
MISSISSIPPI	Baton	79	0.03	0.78	0.22	0.02	1.04	0.19	0.02	1.24	0.17
	Jack Watson	80	0.12	0.75	1.09	0.12	1.00	0.96	0.09	1.20	0.86
	Sweatt	79	0.06	0.78	0.35	0.04	1.04	0.31	0.03	1.24	0.29
	Delta	80	0.10	0.75	0.60	0.07	1.00	0.55	0.05	1.20	0.50
	Hutchins	80	0.04	0.75	0.24	0.03	1.00	0.22	0.02	1.20	0.21
	Rex Brown	80	0.24	0.75	1.43	0.16	1.00	1.27	0.12	1.20	1.16
MISSOURI	Jim Hill	78	0.04	0.80	0.25	0.03	1.08	0.24	0.02	1.28	0.20
	Northern	76	0.22	0.85	1.51	0.15	1.15	1.37	0.11	1.36	1.21
	Montrose	76	0.38	0.85	2.61	0.26	1.15	2.35	0.19	1.36	2.08
	Ralph Green	76	0.04	0.85	0.28	0.03	1.15	0.25	0.02	1.36	0.23
	Sibley	76	0.07	0.85	0.48	0.05	1.15	0.44	0.04	1.36	0.40
	Sturgeon	76	0.02	0.85	0.17	0.02	1.15	0.15	0.01	1.36	0.13
	James R.	76	0.07	0.85	0.48	0.05	1.15	0.44	0.03	1.36	0.38
MONTANA	Frank Bird	69	0.03	1.28	0.32	0.02	1.72	0.27	0.02	2.08	0.26
	Lewis & Clark	69	0.05	1.13	0.47	0.03	1.60	0.44	0.03	1.90	0.38
NEBRASKA	Crumby	71	0.05	0.98	0.47	0.04	1.28	0.38	0.03	1.58	0.34
	Bluffs	66	0.03	1.10	0.29	0.02	1.54	0.26	0.02	1.84	0.26
	Harold Kramer	75	0.04	0.88	0.31	0.03	1.19	0.28	0.02	1.40	0.26
	N. Omaha	75	0.36	0.88	1.81	0.17	1.19	1.64	0.13	1.40	1.45
NEVADA	Clark	59	0.08	1.28	0.84	0.05	1.72	0.74	0.04	2.08	0.67
	Reid Gardner	62	0.05	1.28	0.51	0.03	1.72	0.48	0.03	2.08	0.42
	Sunrise	68	0.05	1.05	0.39	0.03	1.42	0.35	0.02	1.73	0.32
	Tracy	60	0.04	1.28	0.41	0.03	1.72	0.37	0.02	2.08	0.35

TABLE 12

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NEW HAMPSHIRE	Merrimack	72	0.08	0.95	0.63	0.06	1.26	0.56	0.04	1.53	0.59
	Schiller	72	0.12	0.95	0.90	0.08	1.26	0.81	0.06	1.53	0.73
NEW JERSEY	England, B.L.	77	0.19	0.83	1.28	0.13	1.11	1.14	0.10	1.39	1.01
	Sayerville	75	0.22	0.88	1.55	0.15	1.19	1.40	0.11	1.40	1.24
	Werner, E. H.	75	0.07	0.88	0.49	0.05	1.19	0.44	0.03	1.40	0.39
	Gilbert	74	0.09	0.90	0.68	0.06	1.21	0.61	0.05	1.44	0.55
	Bergen	75	0.36	0.88	2.54	0.24	1.19	2.29	0.18	1.40	2.03
	Burlington	76	0.25	0.85	1.69	0.16	1.15	1.51	0.12	1.36	1.35
	Essex	75	0.14	0.88	0.98	0.09	1.19	0.89	0.07	1.40	0.79
	Kearny "B"	75	0.16	0.88	1.16	0.11	1.19	1.04	0.08	1.40	0.92
	Hudson	75	0.18	0.88	1.30	0.12	1.19	1.18	0.09	1.40	1.05
	Marion	75	0.04	0.88	0.31	0.03	1.19	0.28	0.02	1.40	0.24
	Mercer	75	0.39	0.88	2.72	0.26	1.19	2.45	0.19	1.40	2.18
	Sewaren	77	0.45	0.83	3.00	0.30	1.11	2.87	0.23	1.32	2.60
	Vineland	77	0.04	0.83	0.26	0.03	1.11	0.29	0.02	1.32	0.20
NEW MEXICO	Carlsbad	71	0.02	0.98	0.17	0.01	1.28	0.15	0.01	1.58	0.14
	Cunningham	71	0.12	0.98	0.97	0.08	1.28	0.84	0.06	1.58	0.77
	Lordsburgh	67	0.02	1.08	0.19	0.01	1.48	0.17	0.01	1.78	0.16
	Person	65	0.06	1.13	0.52	0.04	1.60	0.49	0.03	1.90	0.44
	Reeves	65	0.14	1.13	1.23	0.09	1.60	1.15	0.07	1.90	1.09
NEW YORK	Dunkirmer	79	0.19	0.95	1.48	0.13	1.26	1.31	0.10	1.53	1.19
	Lovett	73	0.09	0.93	0.66	0.06	1.23	0.59	0.04	1.49	0.53
	Arthur Kill	75	0.20	0.88	1.38	0.13	1.19	1.24	0.10	1.40	1.09
	Astoria	75	0.73	0.88	5.15	0.49	1.19	4.64	0.36	1.40	4.10
	E. River	75	0.89	0.88	9.99	0.58	1.19	9.69	0.71	1.40	9.37
	Hellgate	75	0.41	0.88	9.90	0.27	1.19	9.61	0.21	1.40	9.31
	Hudson	75	0.50	0.88	3.55	0.33	1.19	3.19	0.25	1.40	2.87
	Ravenswood	75	0.64	0.88	4.48	0.47	1.19	4.04	0.35	1.40	3.56
	Sherman Cr.	75	0.12	0.88	0.82	0.08	1.19	0.75	0.06	1.40	0.64
	Waterside	75	0.39	0.88	2.76	0.26	1.19	2.49	0.20	1.40	2.20

TABLE 12

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NEW YORK	Barrett, E. E.	75	0.23	0.88	1.65	0.16	1.19	1.49	0.12	1.40	1.30
	Far Rockaway	75	0.06	0.88	0.46	0.04	1.19	0.42	0.03	1.40	0.37
	Glenwood	75	0.21	0.88	1.48	0.14	1.19	1.33	0.10	1.40	1.18
	Port Jefferson	75	0.27	0.88	1.92	0.18	1.19	1.73	0.14	1.40	1.52
	Goudey	73	0.07	0.93	0.50	0.04	1.23	0.44	0.03	1.49	0.39
	Greenidge	72	0.08	0.95	0.60	0.05	1.26	0.52	0.04	1.53	0.47
	Hickling	73	0.05	0.93	0.36	0.03	1.23	0.32	0.02	1.49	0.30
	Jennison	73	0.02	0.93	0.19	0.02	1.23	0.17	0.01	1.49	0.16
	Milliken	72	0.20	0.95	1.49	0.13	1.26	1.31	0.10	1.53	1.19
	Russel	73	0.18	0.93	1.32	0.12	1.23	1.17	0.09	1.49	1.05
	Carlson, S.A.	73	0.04	0.93	0.33	0.03	1.23	0.30	0.02	1.49	0.25
	Albany	73	0.27	0.93	2.03	0.18	1.23	1.78	0.14	1.49	1.64
	Dunkirk	72	0.34	0.95	2.69	0.23	1.26	2.33	0.17	1.53	2.10
	Huntley, C.R.	72	0.46	0.95	3.49	0.31	1.26	3.09	0.23	1.53	2.80
	Oswego	72	0.18	0.95	1.36	0.12	1.26	1.21	0.09	1.53	1.10
NORTH CAROLINA	Asheville	76	0.12	0.85	0.79	0.08	1.15	0.72	0.06	1.36	0.65
	Cape Fear	77	0.23	0.83	1.53	0.15	1.11	1.37	0.12	1.32	1.23
	Lee, H. F.	78	0.24	0.80	1.56	0.16	1.08	1.40	0.12	1.28	1.25
	Sutton, L. V.	79	0.16	0.78	0.99	0.10	1.04	0.88	0.08	1.24	0.80
	Weatherspoon	78	0.07	0.80	0.47	0.05	1.08	0.43	0.04	1.28	0.39
	Allen, G. G.	76	0.71	0.85	4.80	0.47	1.15	4.35	0.35	1.36	3.86
	Buck	76	0.24	0.85	1.66	0.16	1.15	1.49	0.12	1.36	1.33
	Cliffside	74	0.15	0.90	1.07	0.10	1.21	0.96	0.07	1.44	0.86
	Dan River	76	0.21	0.85	1.40	0.14	1.15	1.27	0.10	1.36	1.12
	Marshall	77	0.19	0.83	1.27	0.13	1.11	1.14	0.10	1.32	1.01
	Riverbend	76	0.32	0.85	2.17	0.21	1.15	1.95	0.16	1.36	1.74
NORTH DAKOTA	Beckett	68	0.05	1.05	0.45	0.04	1.42	0.42	0.03	1.73	0.37
	Wood, F. F.	69	0.05	1.03	0.43	0.03	1.36	0.38	0.02	1.68	0.34
	Devil's Lake	68	0.008	1.05	0.07	0.006	1.42	0.07	0.004	1.73	0.06
	Bison	67	0.01	1.08	0.12	0.009	1.48	0.11	0.006	1.79	0.10

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
OHIO	Beckjord, W. C.	76	0.46	0.85	3.16	0.31	1.15	2.86	0.23	1.36	2.53
	Miami Fort	76	0.22	0.85	1.51	0.15	1.15	1.35	0.11	1.36	1.21
	West End	77	0.11	0.83	0.76	0.08	1.11	0.68	0.06	1.32	0.61
	Ashtabula	73	0.22	0.93	1.62	0.15	1.23	1.43	0.11	1.49	1.30
	Eastlake	73	0.39	0.93	2.88	0.26	1.23	2.53	0.19	1.49	2.30
	Lakeshore	73	0.29	0.93	2.20	0.20	1.23	1.93	0.15	1.49	1.75
	Conesville	74	0.31	0.90	2.27	0.21	1.21	2.03	0.16	1.44	1.82
	Poston	75	0.15	0.88	1.08	0.10	1.19	0.96	0.08	1.40	0.86
	Hutchings, O. H.	76	0.25	0.85	1.70	0.17	1.15	1.53	0.12	1.36	1.35
	Tait, Frank M.	76	0.25	0.85	1.70	0.17	1.15	1.53	0.12	1.36	1.35
	Burger	73	0.30	0.93	2.24	0.20	1.23	1.97	0.15	1.49	1.80
	Edgewater	73	0.06	0.93	0.49	0.04	1.23	0.44	0.03	1.49	0.39
	Gorge	74	0.05	0.90	0.35	0.03	1.21	0.32	0.02	1.44	0.29
	Mad River	75	0.03	0.88	0.21	0.02	1.19	0.19	0.02	1.40	0.18
	Miles	73	0.12	0.93	0.91	0.08	1.23	0.81	0.06	1.49	0.73
	Stuart, W. H.	73	0.55	0.93	4.07	0.36	1.23	3.58	0.27	1.49	3.25
	Toronto	73	0.10	0.93	0.76	0.07	1.23	0.70	0.05	1.49	0.64
	Muskingum	74	0.57	0.90	4.13	0.38	1.21	3.71	0.29	1.44	3.32
	Philo	74	0.21	0.90	1.55	0.14	1.21	1.39	0.11	1.44	1.23
	Tidd	73	0.17	0.93	1.29	0.12	1.23	1.15	0.09	1.49	1.05
	Kyger Cr.	75	0.69	0.88	4.85	0.46	1.19	4.37	0.34	1.40	3.86
	Acme	73	0.10	0.93	0.76	0.07	1.23	0.70	0.05	1.49	0.64
	Bayshore	73	0.28	0.93	2.09	0.19	1.23	1.84	0.14	1.49	1.66
	Vine St.	74	0.02	0.90	0.11	0.01	1.21	0.10	0.008	1.44	0.09
	Avon	73	0.27	0.93	2.03	0.18	1.23	1.78	0.14	1.49	1.62
OKLAHOMA	Arbuckle	76	0.04	0.85	0.26	0.03	1.15	0.25	0.02	1.36	0.21
	Boroughs L.	75	0.29	0.88	2.01	0.19	1.19	1.82	0.14	1.40	1.60
	Mustang	75	0.29	0.88	2.04	0.19	1.19	1.83	0.15	1.40	1.62
	Riverbank	76	0.11	0.85	0.76	0.08	1.15	0.71	0.06	1.36	0.63
	North Eastern	76	0.13	0.85	0.88	0.09	1.15	0.79	0.06	1.36	0.71
	South Western	73	0.11	0.93	0.81	0.07	1.23	0.77	0.05	1.49	0.64
	Tulsa	76	0.30	0.85	2.04	0.20	1.15	1.84	0.15	1.36	1.62
	Welsetin	76	0.05	0.85	0.33	0.03	1.15	0.29	0.02	1.36	0.25
PENNSYLVANIA	Colfax	73	0.26	0.93	2.11	0.19	1.23	1.86	0.14	1.49	1.71
	Elrama	73	0.45	0.93	3.39	0.30	1.23	3.00	0.23	1.49	2.73

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
PENNSYLVANIA	Phillips, F. R.	73	0.38	0.93	2.85	0.25	1.23	2.51	0.19	1.49	2.27
	Reed, J. H.	73	0.16	0.93	1.17	0.10	1.23	1.03	0.08	1.49	0.93
	Crawford	74	0.05	0.90	0.33	0.03	1.21	0.30	0.02	1.44	0.27
	Portland	76	0.29	0.85	2.00	0.20	1.15	1.81	0.15	1.36	1.60
	Titus	76	0.15	0.85	1.05	0.10	1.15	0.95	0.08	1.36	0.85
	Seward	79	0.16	0.95	1.23	0.11	1.26	1.10	0.08	1.53	1.01
	Shawville	75	0.48	0.88	3.39	0.32	1.19	3.07	0.24	1.40	2.71
	Warren	73	0.08	0.93	0.63	0.06	1.23	0.57	0.04	1.49	0.50
	New Castle	73	0.26	0.93	1.93	0.17	1.23	1.71	0.13	1.49	1.55
	Brunner, I.	74	0.29	0.90	2.13	0.20	1.21	1.92	0.15	1.44	1.71
	Holtwood	75	0.16	0.88	1.13	0.11	1.19	1.02	0.08	1.40	0.90
	Martin's Cr.	74	0.20	0.90	1.47	0.14	1.21	1.33	0.10	1.44	1.19
	Stanton	74	0.09	0.90	0.69	0.06	1.21	0.56	0.04	1.44	0.49
	Suburban	74	0.03	0.90	0.21	0.02	1.21	0.19	0.02	1.44	0.18
	Sunbury	75	0.40	0.88	2.82	0.27	1.19	2.54	0.20	1.40	2.24
	Barrenbore	76	0.08	0.85	0.59	0.05	1.15	0.46	0.04	1.36	0.42
	Chester	76	0.10	0.85	0.79	0.07	1.15	0.65	0.05	1.36	0.58
	Crosby	76	0.25	0.85	1.69	0.17	1.15	1.53	0.12	1.36	1.35
	Delaware	76	0.23	0.85	1.57	0.15	1.15	1.41	0.11	1.36	1.25
	Eddystone	76	0.43	0.85	2.95	0.29	1.15	2.67	0.20	1.36	2.36
	Richmond	76	0.28	0.85	1.89	0.19	1.15	1.77	0.14	1.36	1.57
	Schuylkill	76	0.21	0.85	1.47	0.14	1.15	1.37	0.11	1.36	1.18
	Southwark	76	0.19	0.85	1.31	0.13	1.15	1.20	0.10	1.36	1.06
	Armstrong	73	0.29	0.93	2.17	0.19	1.23	1.91	0.15	1.49	1.73
	Milesburg	73	0.05	0.93	0.37	0.03	1.23	0.32	0.03	1.49	0.30
	Springdale	73	0.28	0.93	2.09	0.19	1.23	1.84	0.14	1.49	1.66
	Mitchell	73	0.35	0.93	2.61	0.23	1.23	2.29	0.18	1.49	2.09
RHODE ISLAND	Manchester St.	74	0.08	0.90	0.61	0.06	1.21	0.54	0.04	1.44	0.49
	South St.	74	0.10	0.90	0.74	0.07	1.21	0.67	0.05	1.44	0.60
SOUTH CAROLINA	Dunnards Mount	77	0.02	0.83	0.16	0.02	1.11	0.14	0.01	1.32	0.13
	Pinopolis	79	0.04	0.78	0.38	0.03	1.04	0.34	0.02	1.24	0.33
	Robinson, H. B.	78	0.12	0.98	0.94	0.08	1.28	0.82	0.06	1.58	0.77
	Hagood	79	0.02	0.78	0.19	0.02	1.04	0.18	0.02	1.24	0.16
	Silas McKenzie	78	0.17	0.80	1.10	0.11	1.08	0.99	0.09	1.28	0.88
	Urquhart	78	0.14	0.80	0.92	0.09	1.08	0.83	0.07	1.28	0.75
	Lee, W. S.	77	0.27	0.83	1.81	0.18	1.11	1.61	0.14	1.32	1.45
	Cundys	79	0.14	0.78	0.87	0.09	1.04	0.78	0.07	1.24	0.70

Capital Cost of Mechanical Draft Cooling Towers

State	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
SOUTH DAKOTA	Ben French	68	0.09	1.05	0.13	0.01	1.49	0.13	0.008	1.73	0.11
	Aberdeen	71	0.01	0.98	0.11	0.009	1.38	0.10	0.007	1.58	0.09
	Mitchell	73	0.01	0.93	0.09	0.008	1.33	0.08	0.006	1.49	0.07
	Lawrence	74	0.83	0.90	0.94	0.07	1.31	0.13	0.07	1.44	0.10
TENNESSEE	Johnsonville "A"	78	0.90	0.80	1.78	0.13	1.08	1.16	0.10	1.38	1.07
	Johnsonville "B"	78	0.49	0.80	9.68	0.38	1.08	9.49	0.31	1.38	9.15
	John Sevier	75	0.38	0.88	9.66	0.35	1.19	9.40	0.19	1.40	9.11
	Gallatin	78	0.44	0.80	9.79	0.39	1.08	9.59	0.29	1.38	9.75
	Kingston	75	0.90	0.88	6.46	0.61	1.19	5.87	0.46	1.40	5.14
	Allen, Thos. H.	79	0.16	0.78	1.03	0.11	1.04	0.99	0.08	1.24	0.89
TEXAS	Bates, J. L.	78	0.13	0.80	0.81	0.08	1.08	0.73	0.06	1.34	0.63
	Lon Hill	77	0.17	0.83	1.10	0.11	1.11	0.98	0.08	1.39	0.89
	La Palma	78	0.03	0.80	0.19	0.02	1.08	0.17	0.01	1.34	0.12
	Laredo	77	0.04	0.83	0.88	0.03	1.11	0.86	0.09	1.32	0.93
	Nueces Bay	78	0.07	0.80	0.44	0.05	1.08	0.40	0.03	1.34	0.34
	Victoria	78	0.18	0.80	1.15	0.12	1.08	1.04	0.09	1.38	0.99
	Dallas	77	0.06	0.83	0.49	0.04	1.11	0.38	0.03	1.39	0.35
	Mt. Creek	77	0.13	0.83	0.84	0.08	1.11	0.75	0.06	1.39	0.67
	N. Lake	77	0.31	0.83	9.08	0.21	1.11	1.85	0.16	1.39	1.65
	Parkdale	77	0.15	0.83	0.98	0.10	1.11	0.87	0.07	1.39	0.79
	Nueces	69	0.13	1.03	1.04	0.08	1.36	0.99	0.06	1.68	0.85
	Sabine	79	0.23	0.78	1.49	0.15	1.04	1.27	0.11	1.34	1.14
	Graham	76	0.14	0.85	0.99	0.09	1.15	0.83	0.07	1.36	0.73
	Handley	77	0.99	0.83	1.50	0.15	1.11	1.34	0.11	1.39	1.19
	Morgan Cr.	73	0.25	0.93	1.87	0.17	1.23	1.65	0.13	1.49	1.50
	Permian Basin	79	0.15	0.95	1.18	0.10	1.26	1.04	0.08	1.53	0.96
	Collin County	77	0.08	0.83	0.58	0.05	1.11	0.48	0.04	1.39	0.43
	Lake Creek	77	0.89	0.83	1.47	0.15	1.11	1.89	0.11	1.39	1.17
	River Crest	78	0.04	0.80	0.84	0.09	1.08	0.99	0.09	1.38	0.90
	Sturgeon Cr.	78	0.16	0.88	1.03	0.11	1.08	0.93	0.08	1.38	0.89
	Valley	74	0.12	0.90	0.85	0.08	1.21	0.76	0.06	1.44	0.68
	Comanche	74	0.02	0.90	0.18	0.02	1.21	0.17	0.01	1.44	0.15
	Oak Creek	74	0.07	0.90	0.54	0.05	1.21	0.48	0.04	1.44	0.47
	Nechas	79	0.44	0.78	9.79	0.29	1.04	9.43	0.22	1.34	9.18
	Paint Cr.	74	0.08	0.90	0.55	0.05	1.21	0.50	0.04	1.44	0.44
	L. Pauline	73	0.02	0.93	0.16	0.01	1.23	0.15	0.01	1.49	0.13
	Rio Pecos	74	0.04	0.90	0.32	0.03	1.21	0.30	0.02	1.44	0.27
	Knox Lee	79	0.09	0.78	0.54	0.06	1.04	0.48	0.04	1.34	0.42

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Temperature °F	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M GPM	RANGE 20° F. Relative Water M GPM	RANGE 20° F. Cost, Tower Million Dollars
TEXAS	Lone Star	79	0.04	0.78	0.23	0.02	1.04	0.31	0.01	1.24	0.19
	Wilkes	79	0.14	0.78	0.87	0.09	1.04	0.76	0.07	1.24	0.66
	Rio Grande	69	0.06	1.03	0.71	0.06	1.36	0.63	0.04	1.68	0.57
	Sam Bertron	79	0.61	0.78	3.78	0.40	1.04	3.36	0.30	1.24	3.00
	Clarke, H. O.	79	0.05	0.78	0.34	0.04	1.04	0.30	0.03	1.24	0.27
	Deepwater	79	0.14	0.78	0.90	0.10	1.04	0.80	0.07	1.24	0.72
	Greens Bayou	79	0.13	0.78	0.81	0.09	1.04	0.73	0.06	1.24	0.65
	Parrish, W. A.	79	1.43	0.78	9.71	0.99	1.04	8.41	0.69	1.24	8.16
	Webster	79	0.29	0.78	1.81	0.19	1.04	1.60	0.15	1.24	1.44
	Wharton, T. E.	79	0.16	0.78	1.14	0.12	1.04	1.02	0.09	1.24	0.91
	Leon Cr.	77	0.07	0.83	0.47	0.05	1.11	0.41	0.03	1.32	0.37
	Mission Rd.	77	0.06	0.83	0.41	0.04	1.11	0.38	0.03	1.32	0.33
	Tuttle, W. B.	77	0.21	0.83	1.37	0.14	1.11	1.22	0.10	1.32	1.09
	Denver City	77	0.10	0.83	0.65	0.06	1.11	0.58	0.05	1.32	0.53
	East	70	0.06	1.00	0.45	0.04	1.30	0.40	0.03	1.69	0.37
	Moore County	70	0.06	1.00	0.48	0.04	1.30	0.42	0.03	1.69	0.40
	Nichols	70	0.12	1.00	0.96	0.08	1.30	0.84	0.06	1.69	0.79
	Plant "X"	71	0.20	0.98	1.54	0.13	1.28	1.35	0.10	1.58	1.26
	Riverview	71	0.05	0.09	0.39	0.03	1.28	0.34	0.07	1.58	0.32
	Tuco	71	0.07	0.98	0.15	0.01	1.28	0.13	0.01	1.58	0.13
	Eagle Mt.	77	0.12	0.83	0.83	0.08	1.11	0.73	0.06	1.32	0.69
UTAH	Carbon County, SEC. I	65	0.03	1.13	0.25	0.02	1.60	0.24	0.01	1.90	0.21
	Carbon County, SEC. II	65	0.07	1.13	0.61	0.05	1.60	0.59	0.03	1.90	0.53
	Gadsby, SEC. I	65	0.04	1.13	0.40	0.03	1.60	0.39	0.02	1.90	0.35
	Gadsby, SEC. II	65	0.04	1.13	0.40	0.03	1.60	0.39	0.02	1.90	0.35
	Gadsby, SEC. III	65	0.07	1.13	0.68	0.05	1.60	0.64	0.04	1.90	0.55
	Provo	65	0.01	1.13	0.09	0.006	1.60	0.08	0.005	1.90	0.08
VERMONT	Moran, J. Edward	71	0.09	0.98	0.14	0.01	1.28	0.12	0.008	1.58	0.11
VIRGINIA	Potomac R.	78	0.22	0.80	1.42	0.15	1.08	1.29	0.11	1.38	1.13
	Riverton	74	0.02	0.90	0.14	0.01	1.21	0.13	0.01	1.44	0.11
	Bremo	74	0.15	0.90	1.09	0.10	1.21	0.96	0.07	1.44	0.86
	Chesterfield	75	0.43	0.88	3.00	0.28	1.19	2.70	0.21	1.40	2.39
	Portsmouth	78	0.35	0.80	2.27	0.24	1.08	2.04	0.18	1.38	1.85
	Possum Point	75	0.29	0.88	2.01	0.19	1.19	1.89	0.14	1.40	1.60
	Yorktown	78	0.46	0.80	2.93	0.30	1.08	2.64	0.23	1.38	2.36
	Clinch R.	75	0.48	0.88	3.35	0.32	1.19	3.03	0.24	1.40	2.67
	Glen Lyn	75	0.22	0.88	1.57	0.15	1.19	1.42	0.11	1.40	1.26

TABLE 12

Capital Cost of Mechanical Draft Cooling Towers

STATE	Name of Plant	Wet Temperature of	RANGE 10° F. Cooling Water M/GPM	RANGE 10° F. Relative Rating Factor	RANGE 10° F. Cost, Tower Million Dollars	RANGE 15° F. Cooling Water M/GPM	RANGE 15° F. Relative Water M/GPM	RANGE 15° F. Cost, Tower Million Dollars	RANGE 20° F. Cooling Water M/GPM	RANGE 20° F. Relative Water M/GPM	RANGE 20° F. Cost, Tower Million Dollars
WEST VIRGINIA	Cabin Cr.	73	0.06	0.93	0.43	0.04	1.23	0.38	0.03	1.49	0.35
	Kanawha R.	74	0.31	0.90	2.25	0.21	1.21	2.01	0.16	1.44	1.80
	Phillip Sporn	75	0.67	0.88	4.69	0.44	1.19	4.23	0.33	1.40	3.73
	Windsor	73	0.17	0.93	1.26	0.11	1.23	1.11	0.08	1.49	1.00
	Albright	72	0.30	0.95	2.26	0.20	1.26	2.00	0.15	1.53	1.80
	Kammer	74	0.18	0.90	1.33	0.12	1.21	1.20	0.09	1.44	1.08
	Rivesville	73	0.17	0.93	1.29	0.12	1.23	1.15	0.09	1.49	1.05
	Willow Island	74	0.19	0.90	1.87	0.12	1.21	1.20	0.09	1.44	1.08
WISCONSIN	Bay Front	71	0.05	0.98	0.38	0.03	1.28	0.34	0.02	1.58	0.30
	Blount St.	75	0.12	0.88	0.86	0.08	1.19	0.78	0.06	1.40	0.69
	Menasha	73	0.01	0.93	0.09	0.008	1.23	0.08	0.006	1.49	0.07
	Winslow	71	0.02	0.98	0.17	0.02	1.28	0.16	0.01	1.58	0.15
	N. Oak Cr.	74	0.28	0.90	2.03	0.19	1.21	1.83	0.14	1.44	1.63
	S. Oak Cr.	74	0.40	0.90	2.87	0.26	1.21	2.56	0.20	1.44	2.28
	French Island	76	0.02	0.85	0.17	0.02	1.15	0.16	0.01	1.36	0.14
	Port Washington	74	0.17	0.90	1.24	0.11	1.21	1.11	0.09	1.44	0.99
	Black Hawk	75	0.02	0.88	0.18	0.02	1.19	0.16	0.01	1.40	0.14
	Edgewater	73	0.05	0.93	0.34	0.03	1.23	0.30	0.02	1.49	0.26
	Rock River	75	0.09	0.88	0.65	0.06	1.19	0.58	0.05	1.40	0.52
	Nelson Dewey	76	0.14	0.85	0.96	0.09	1.15	0.86	0.07	1.36	0.77
	Pulliam	72	0.21	0.95	1.58	0.14	1.26	1.40	0.10	1.53	1.29
	Weston	73	0.15	0.93	1.15	0.10	1.23	1.02	0.08	1.49	0.93
	Alma	74	0.15	0.90	1.10	0.10	1.21	0.98	0.08	1.44	0.88
	Stoneman	76	0.03	0.85	0.24	0.02	1.15	0.21	0.02	1.36	0.19
WYOMING	Dave Johnston	62	0.21	1.26	2.11	0.14	1.72	1.89	0.10	2.08	1.71
	Naughton	60	0.09	1.38	1.01	0.06	1.80	0.88	0.05	2.20	0.81
	Osage	66	0.05	1.10	0.46	0.03	1.54	0.43	0.02	1.84	0.37

NOTES:

1 - Wet Bulb Temperatures were interpolated from a graph in "Cooling Towers For Industry" by K. K. McKelvey & Maxey Brooke, 1959.

2 - Relative Rating Factors were interpolated from graphs in "Water Demand for Steam-Electric Generation" by P. H. Cootner and G. O. Lof.

3 - Three range temperatures selected were based on the rise in temperature of the cooling water.

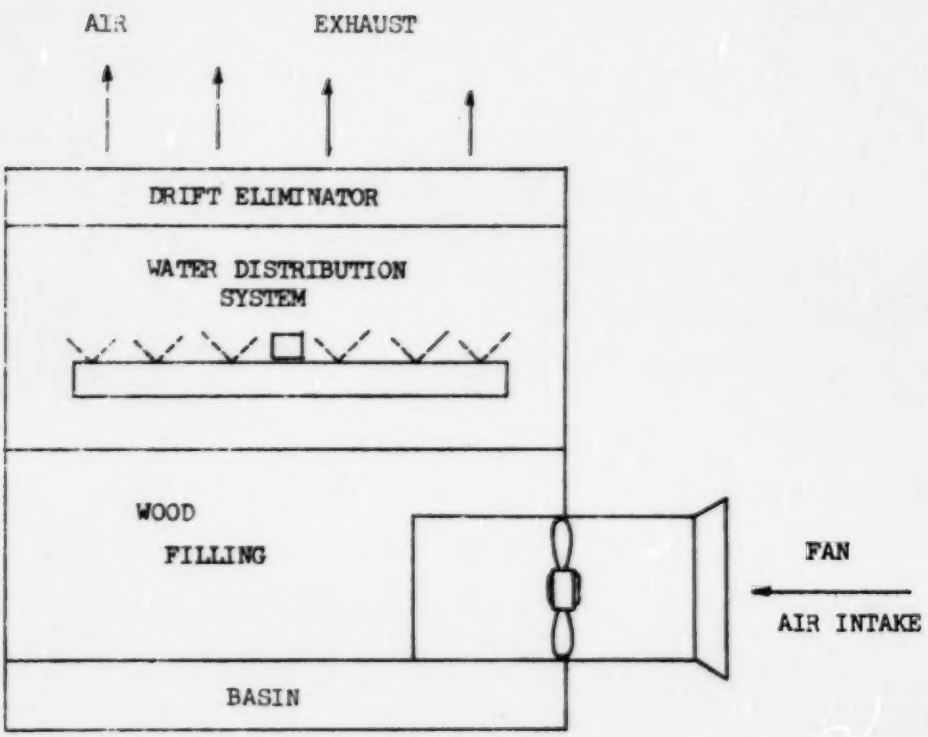


FIGURE 9

FORCED DRAFT TOWER

APPENDIX IV

OTHER METHODS OF POWER GENERATION

METHODS IN USE

Production of power by methods that do not use a steam cycle result in reduction of thermal pollution. Examples of these methods, which are in commercial use at present, are: Gas Turbines, Diesel Engines, and Hydro-electricity.

Gas Turbines[49]

Gas Turbines up to 30,000 kilowatt rating are in use at present and rated capacities up to 121,000 kilowatt are expected. (These units come pre-packaged including their cooling system). The principal advantage is low capital cost of installation, $80.00 to $125.00 per kilowatt. The main disadvantage is the low thermal efficiencies, requiring 15,000 to 18,000 BTU's per kilowatt-hour of generation.

Diesel Engines[49]

Diesel Engines up to 10,000 kilowatt have been installed. These generators also have their own cooling system. The capital cost of installation is about $100.00 per kilowatt and the net heat rate is about 12,000 BTU's per kilowatt-hour of generation.

NOTE: Both Gas Turbines and Diesel Engines are primarily used in peaking operations.

Hydro-electric Generation

Hydro-electric Generation uses the kinetic energy of falling water to drive a water wheel which in turn drives a generator. The estimated hydro-electric potential of the United States is over 141 million kilowatts, out of which 29 million kilowatts have been developed and an additional 36 million kilowatts are expected to be installed by 1980.(50) The cost of hydro-electric generation varies from area to area and depends on the water resources available, development of the resources including construction of a dam or pumped storage facility and installation of the generating plant.

METHODS IN DEVELOPMENTAL STAGE

Other methods of power generation are being developed which are in the experimental stage at present and are not used commercially as yet. Some of these methods were developed primarily for space crafts. Following is a brief description of the various methods of power generation:

Thermo-electric Generation[49]

A thermo-electric generator consists of two dissimilar metal conductors, joined at one end, as shown in Figure 12. Heat, applied at the joined end, increases the electron activity in the conductors, the increase in activity being greater in one than the other. This difference in electron activities in the two conductors produces a potential difference. The heat source can be radioactive isotopes or hydro-carbon fuels.

Thermo-electric generators up to 5 kilowatts have been built. Generators to produce up to 200 kilowatts are predicted to be in operation by 1980. The main drawback of this type of generator is the low overall efficiency of about 10 percent.

Thermionic Generator[49]

Thermionic Generators are based on the principle that

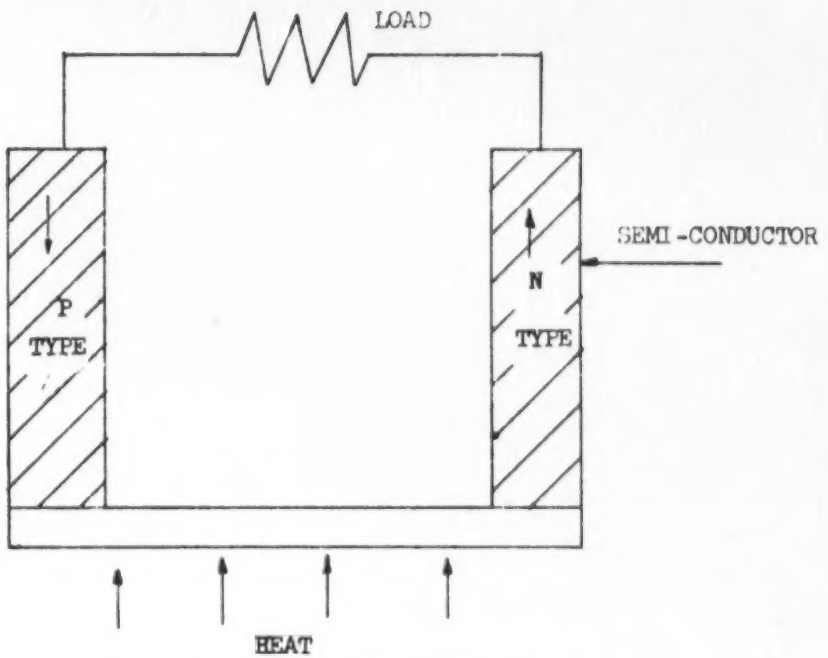


FIGURE 12 THERMOELECTRIC GENERATOR

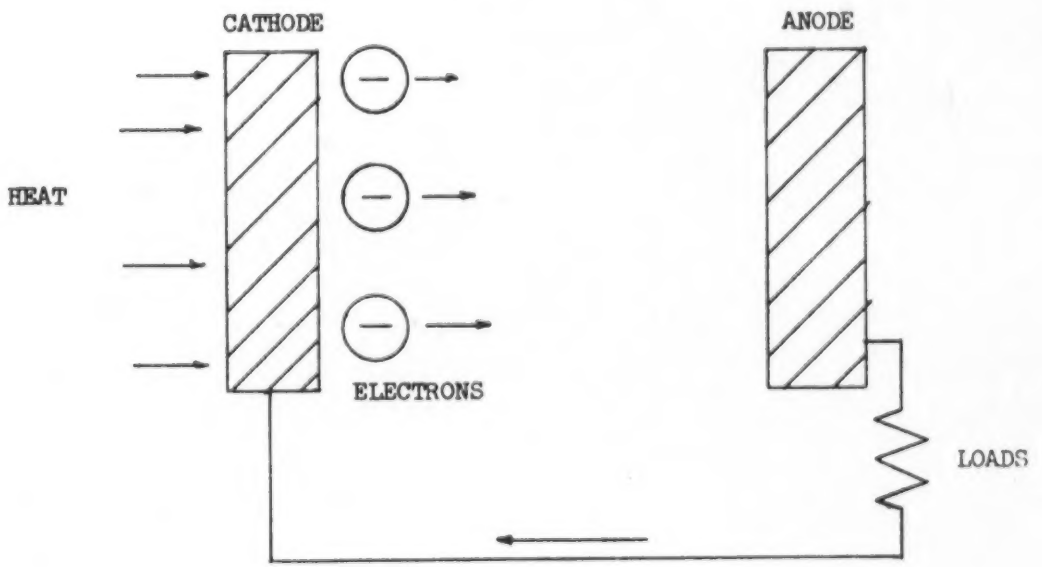


FIGURE 13

THERMIONIC GENERATOR

electrons are emitted by metals at high temperatures. Figure 13 shows the Thermionic Generator Schematically. An electron emitter, called a Cathode, is heated to produce electrons. These electrons, having acquired sufficient energy, travel through the gap to the electron collector, called an Anode, which is at a lower temperature than the Cathode. An electrical potential is created and a current flows through the external load. Nuclear reactors or hydrocarbon fuels can be used as heat sources.

Predictions for this type of generator are that up to 100 kilowatts can be produced by 1970 and larger units may be available by 1975. The present efficiency of the generator is under 10 percent but is expected to be 30 to 40 percent ultimately. If used in conjunction with conventional steam cycles, this type of generator could increase the efficiency of nuclear steam plants by about 15 percent.

Fuel Cells[49] [51]

Fuel Cells are electro-chemical cells in which the chemical energy of oxidation of conventional fuels is converted directly into low voltage current. Fuels, generally used in a fuel cell, are: hydrogen; compromise fuels such as, alcohol, ammonia, hydrazine; or hydro-carbons such as fossil fuel, coal, pure carbon. During combustion, the fuel, at the anode, tends to give up electrons. These electrons flow through an external circuit, where they can do work, to the cathode and are captured by oxygen. Figure 14 shows a Hydrogen-Oxygen cell schematically. Here hydro-

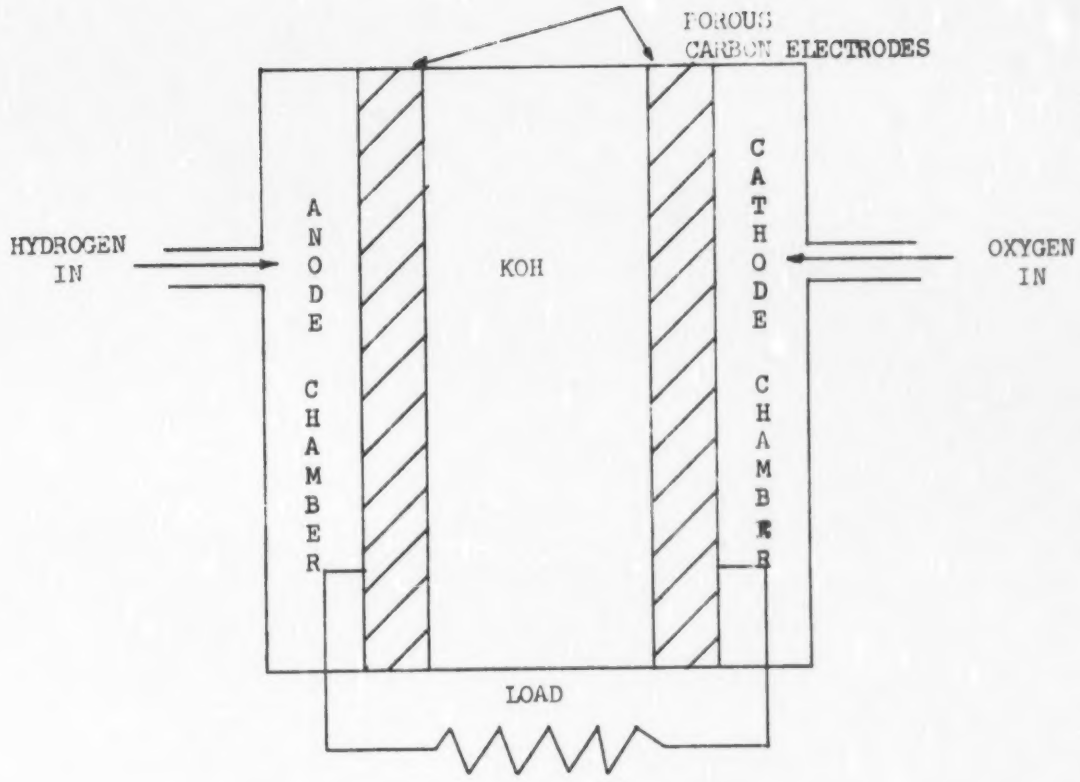


FIGURE 14

HYDROGEN-OXYGEN FUEL CELL

gen is the fuel that gives up electrons due to combustion. These electrons flow, through the external load, to the cathode where they combine with oxygen to form water.

Fuel Cells are not limited to Carnot efficiencies because they produce electricity by oxidation of fuels. The overall efficiency of the cell could approach 60 percent. It is estimated that by 1975, cells of sizes up to 100 kilowatts and by 1980, up to 1,000 kilowatts will be available.

Magnetohydrodynamic(MHD) Generator[49]

A magnetohydrodynamic generator works on the same principle as a conventional generator except that an ionized gas instead of a solid conductor is moving across a magnetic field. Figure 15 shows a Schematic Diagram of a MHD Generator. By placing electrodes in this gas stream, direct current electricity of high potential, 2,000 volts or more, can be obtained.

The major problem with this type of generator is ionization of gas. Gases have to be heated to very high temperatures, up to 5,000° F., for ionization. Research has indicated that gases can be ionized by using non-thermal methods, which might allow lower gas temperatures. Since the temperature of the gas exhausted by a MHD Generator is high, it may be economical to use it in conjunction with a steam cycle.

These generators are best suited for 300 megawatts to over 1,000 megawatts plant size, when combined with conventional steam plants. The overall efficiency of the combination generator is in range of 55 percent to 60 percent, as opposed to 40 percent

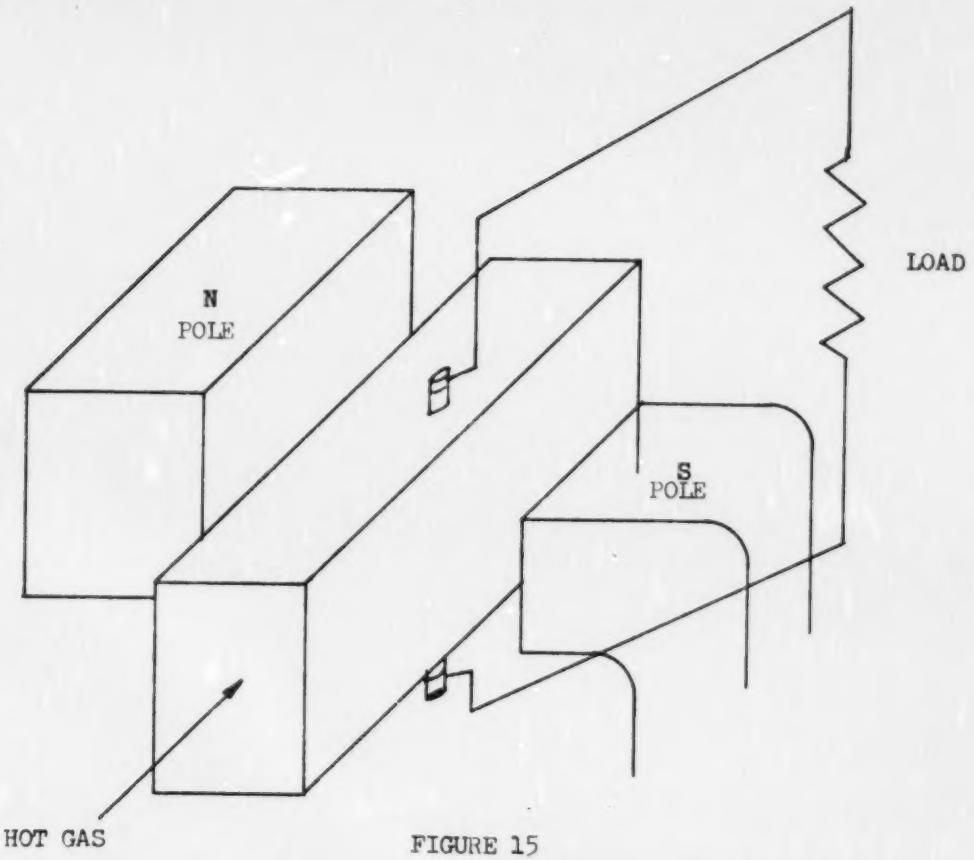
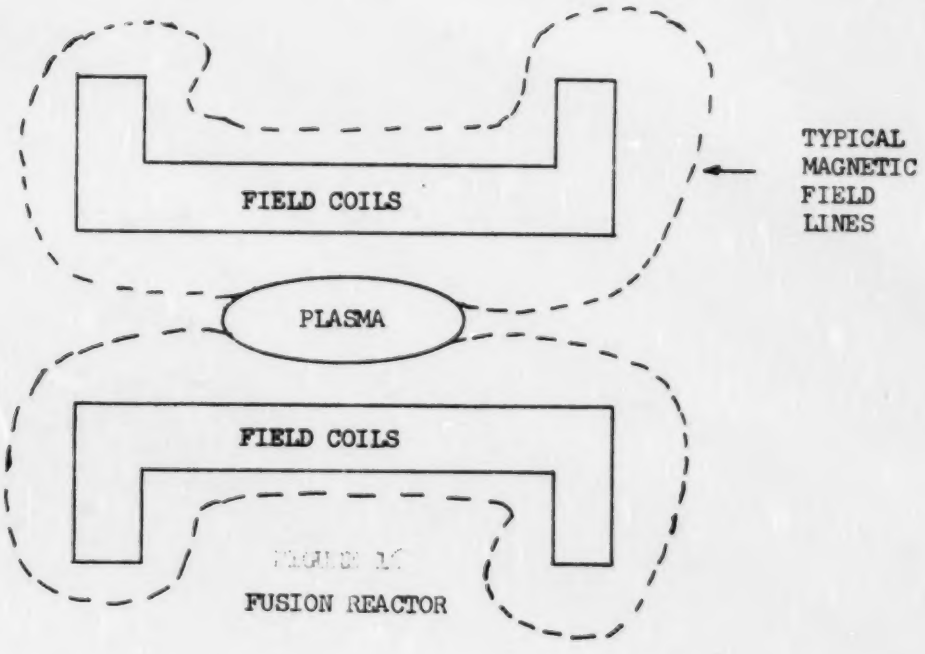


FIGURE 15

MHD GENERATOR



FUSION REACTOR

efficiency of a conventional plant. The combination generator could reduce the net heat rates to about 6,000 BTU's per kilowatt-hour as compared to heat rate of 8,250 BTU's per kilowatt-hour of the best conventional steam plant.

Fusion Reactor[49]

Energy is released in thermo-nuclear fusion when atomic nuclei of light elements combine to form new and heavier elements. The speed at which these nuclear particles travel is a function of temperature. The speeds needed for thermo-nuclear fusion correspond to temperatures in the range of 40 to 100 million degrees Fahrenheit, which is far greater than the temperature needed to dissociate gas molecules of hydrogen, deuterium or tritium into their respective individual atoms and for separation of their orbital electrons from the nuclei. A mixture of nuclei and unattached electrons is called "Plasma," which is a very good conductor of electricity. Solid materials do not exist at these temperatures and hence, the hot plasma is contained in magnetic fields. Schematic diagram of a plasma contained in a magnetic field is shown in Figure 16[49].

It appears possible that some of the energy released in fusion may be recovered as electrical energy. This type of reactor still needs intensive research before it can be developed for commercial use. The main advantages of the reactor are:

1. No radioactive waste disposal problem.
2. The fuel supply is unlimited since the oceans have an inexhaustible supply of heavy water (deuterium oxide).

APPENDIX V

SCHEMATIC DIAGRAMS AND ENTROPY DIAGRAMS FOR STEAM CYCLES

POWER GENERATION

Figure17 [17] shows the apparatus required for power generation schematically.

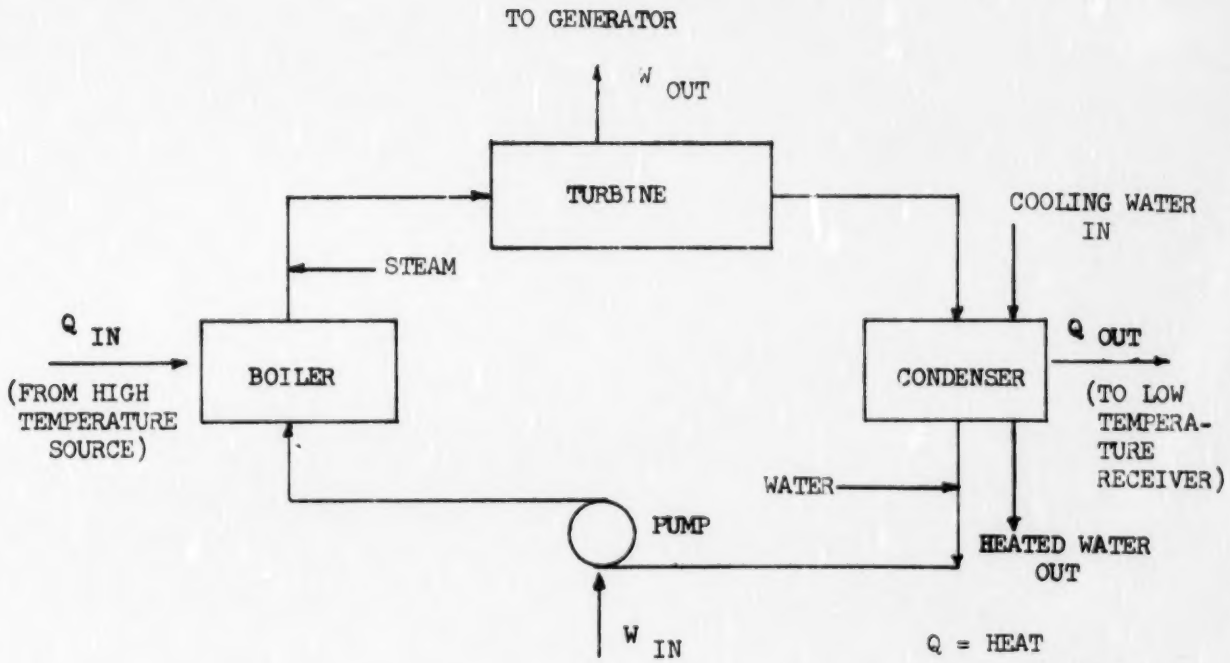


FIGURE 17

APPARATUS FOR POWER GENERATION

Basic steam cycles are:

1. Carnot Cycle (Ideal and Theoretical).
2. Rankine Cycle (Practical).

CARNOT CYCLE

Entropy Diagram is shown in Figure 18

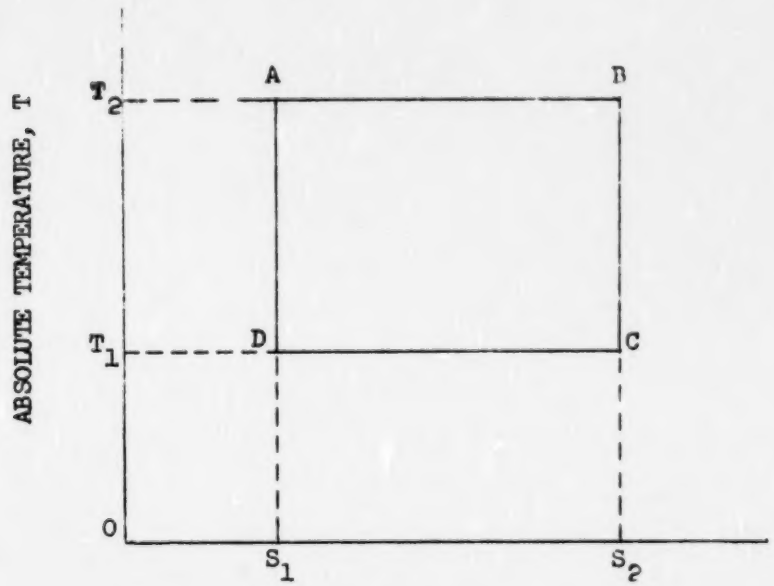


FIGURE 18

ENTROPY DIAGRAM FOR CARNOT CYCLE

Overall thermal efficiency of a Carnot Cycle is:

$$E = \frac{\text{Area ABCD}}{\text{Area AB } S_2S_1} = \frac{Q_{IN} - Q_{OUT}}{Q_{IN}} = \frac{(T_2 - T_1)(S_2 - S_1)}{T_2 (S_2 - S_1)}$$

$$= \frac{T_2 - T_1}{T_1} \qquad (16)$$

RANKINE CYCLE

Figure 19 shows the Entropy Diagram for a Rankine Cycle.

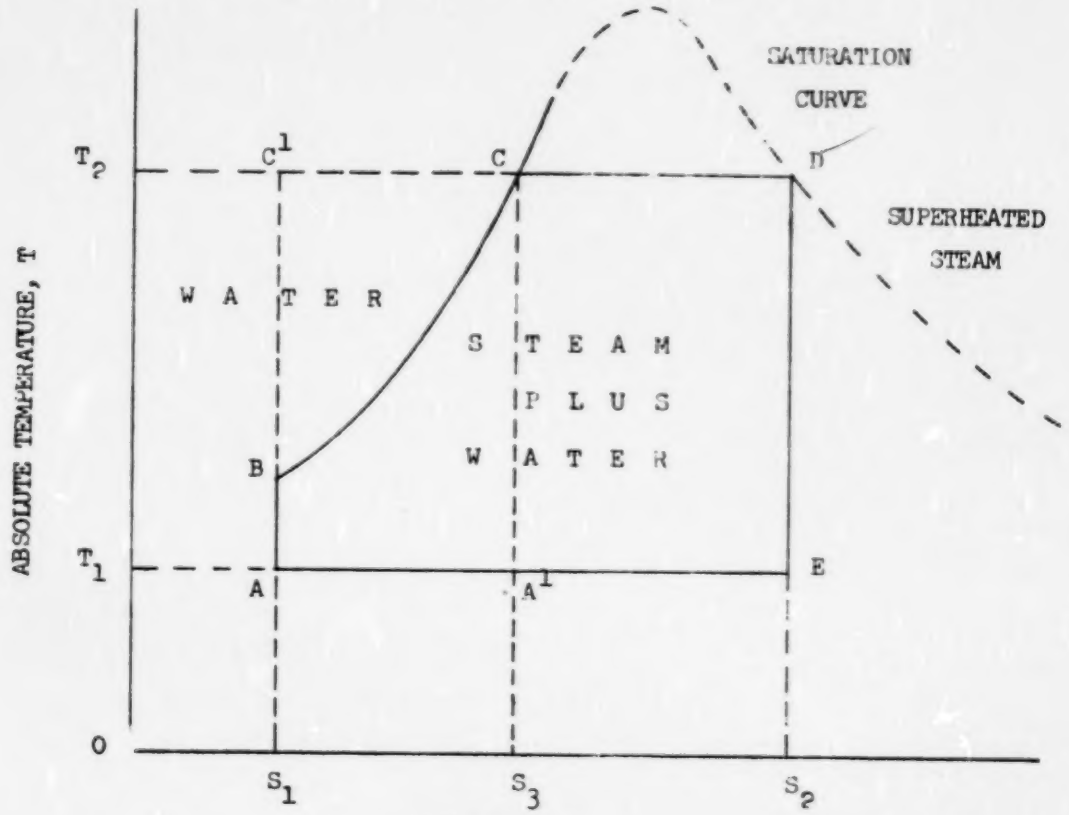


FIGURE 19
ENTROPY DIAGRAM FOR RANKINE CYCLE

Overall thermal efficiency of the Rankine Cycle is:

$$E = \frac{\text{Area ABCDE}}{\text{Area ABCD } S_1 S_2}$$

$$= \frac{Q_{IN} - Q_{OUT}}{Q_{IN}} \qquad (17)$$

METHODS OF INCREASING THERMAL EFFICIENCIES OF STEAM CYCLES

Following are the methods:

1. Feedwater Heating.
2. Superheating.
3. Reheating.

FEEDWATER HEATING

Figure 20 [52] shows the Schematic Diagram for a feedwater heater.

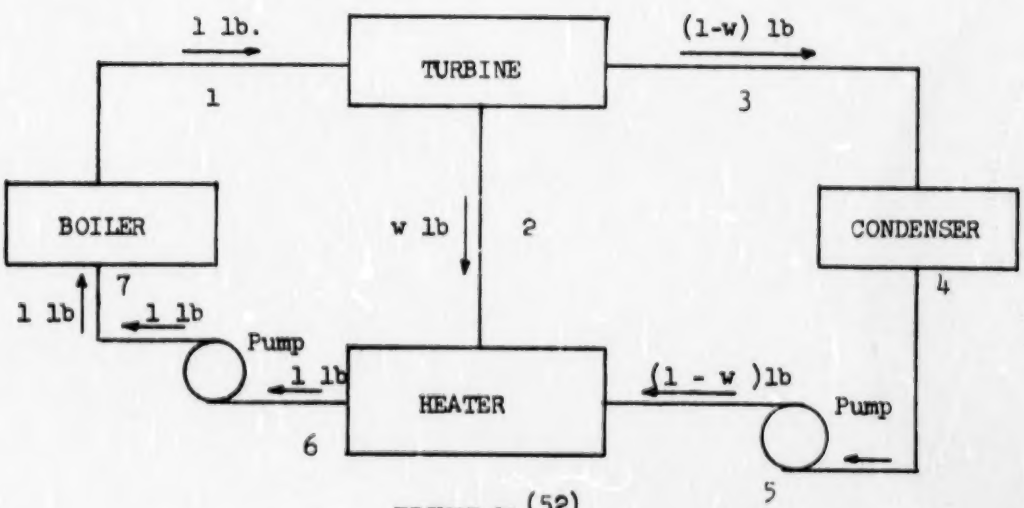


FIGURE 20 [52]

SCHEMATIC DIAGRAM FOR FEEDWATER HEATER

where: 1 lb. = wt. of working fluid

w = wt. of steam withdrawn

Figure 21[52] shows the Entropy Diagram for the feedwater heater.

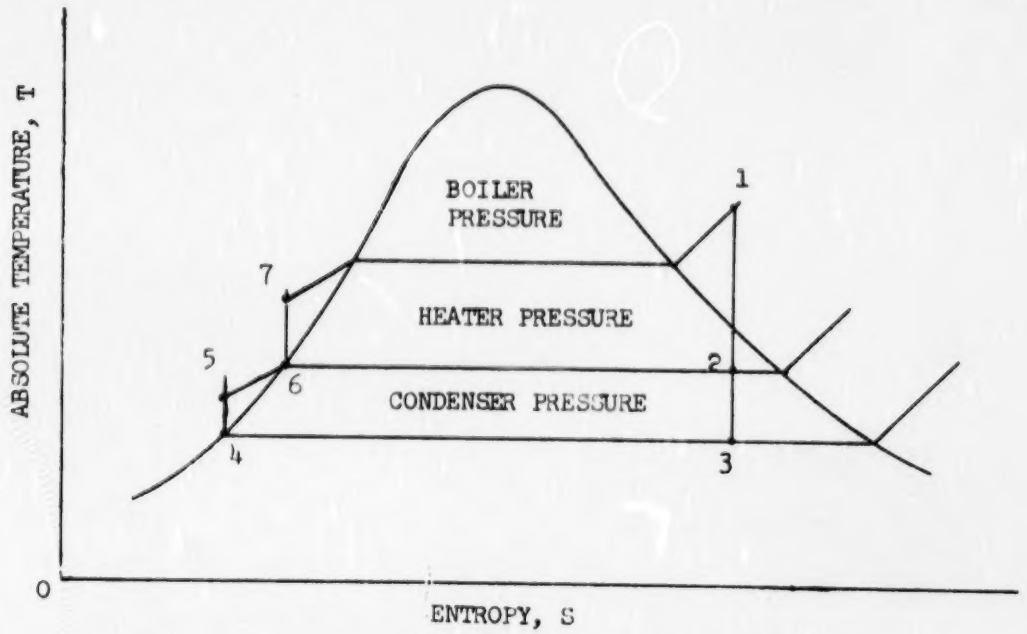


FIGURE 21
ENTROPY DIAGRAM FOR FEEDWATER HEATER

Overall thermal efficiency of a Steam Cycle with feedwater heating is:

$Q_{IN} = h_1 - h_7$ where "h" denotes the heat in the working fluid at a step denoted by the subscript.

$Q_{OUT} = (1-W)\ (h_3 - h_4)$

$$E = \frac{Q_{IN} - Q_{OUT}}{Q_{IN}} = \frac{(h_1 - h_7) - (1-W)\ (h_3 - h_4)}{(h_1 - h_7)} \qquad (18)$$

SUPERHEATING

Figure 22 (53) shows the Entropy Diagram for a Steam Cycle with a superheater.

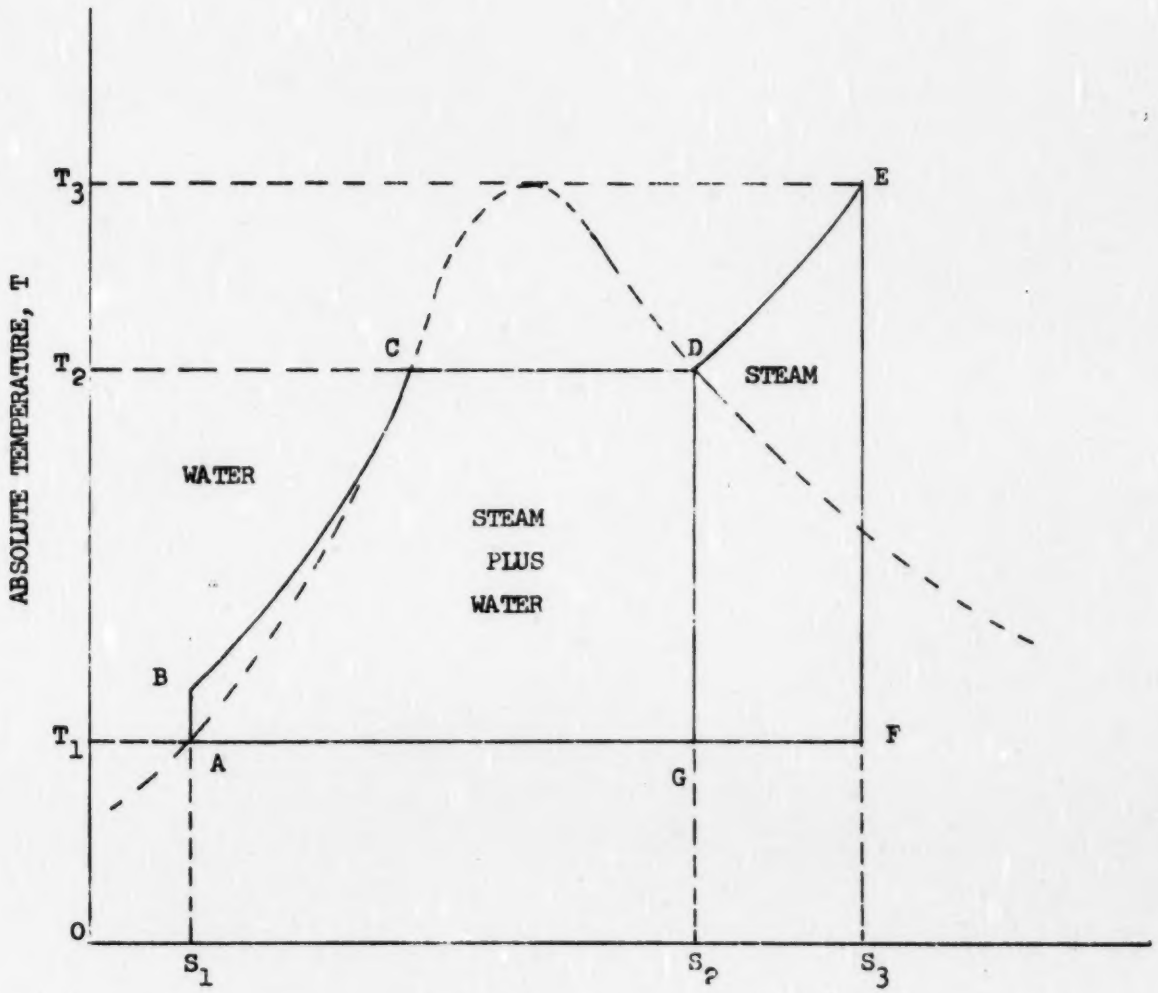


FIGURE 22

ENTROPY DIAGRAM FOR SUPERHEATING

Overall thermal efficiency of a Steam Cycle with superheating is:

$$E = \frac{\text{Area ABCDEFA}}{\text{Area } S_1 \text{ ABCDEFS}_3} \qquad (19)$$

REHEATING

Figure 23 (54) shows a Schematic Diagram for a Steam Cycle with a reheater.

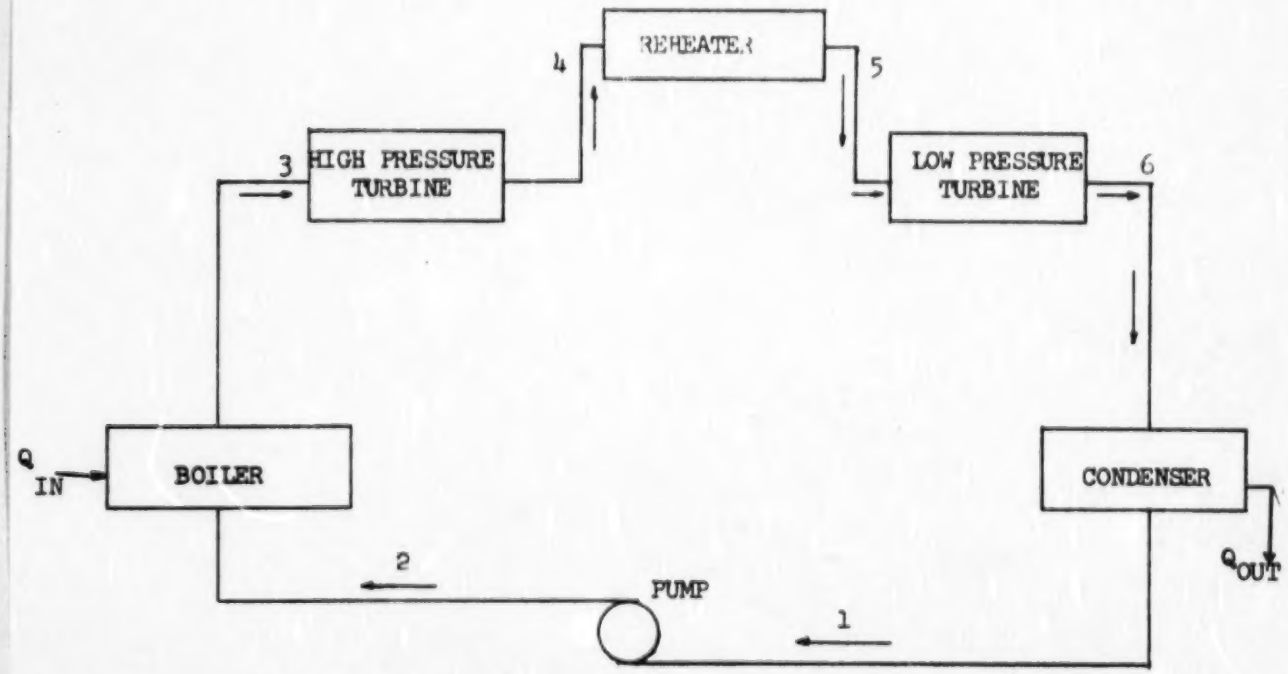


FIGURE 23

SCHEMATIC DIAGRAM OF A REHEATER

Figure 24 (54) shows the Entropy Diagram for a Steam Cycle with a reheater.

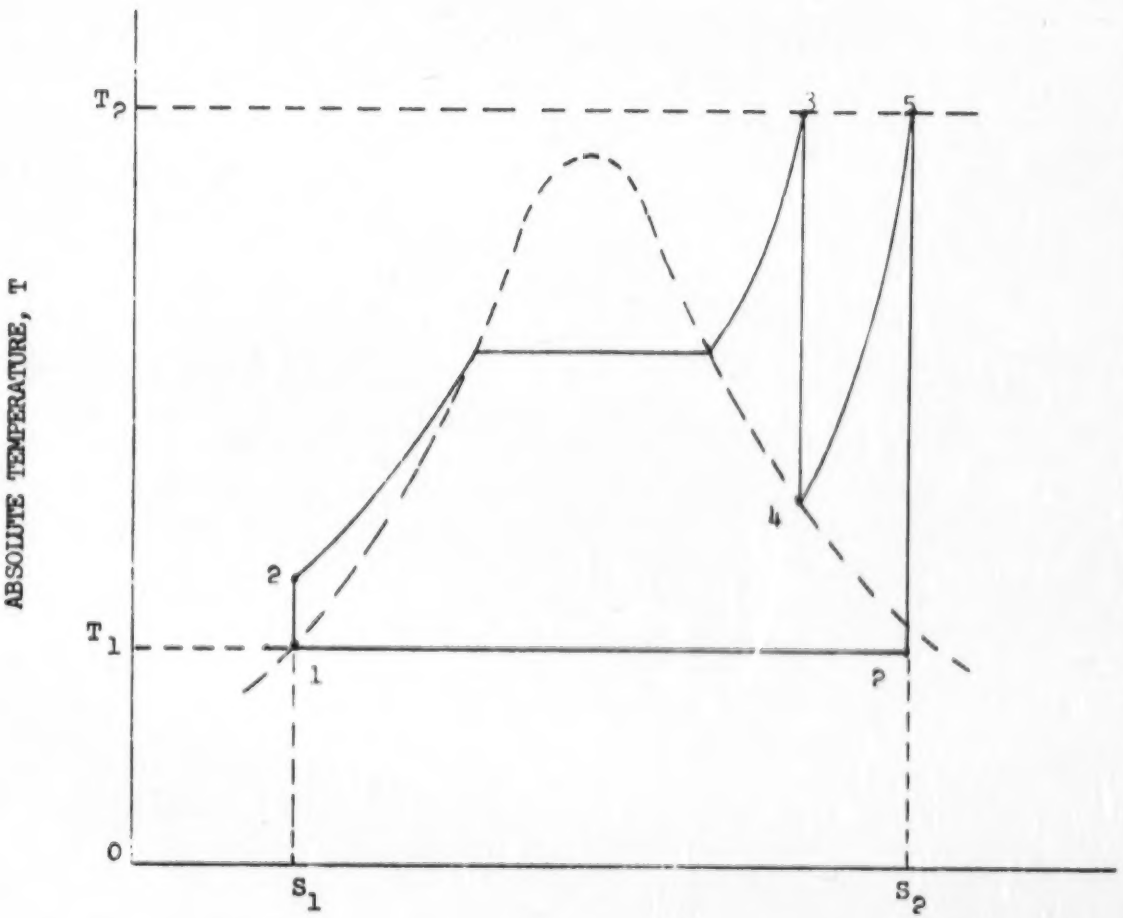


FIGURE 24 (54)

ENTROPY DIAGRAM FOR A REHEATER

Overall thermal efficiency is:

$$E = \frac{Q_{IN} - Q_{OUT}}{Q_{IN}} \qquad (20)$$

where $Q_{IN} = (h_3 - h_2) + (h_5 - h_4)$

$Q_{OUT} = (h_6 - h_1)$

where "h" is the heat of the working fluid at the step denoted by the subscript.

APPENDIX VI

DERIVATION OF RATE CONSTANT EQUATIONS

van't Hoff-Arrhenius Law can be expressed by the following equation:

$$\frac{d(\ln k)}{dT} = \frac{E}{RT^2} \quad (39) \qquad (4)$$

Integration of Equation (4) gives:

$$\ln k = \frac{-E}{RT} + C_1 \text{ , assuming E to be constant} \qquad (21)$$

or

$$\log_{10} k = \frac{-E}{2.303\,R} \frac{1}{T} + C_2 \qquad (22)$$

If k_1 is the rate constant at temperature T_1 and k_1^1 is the rate constant at temperature T_2, then, integration of Equation (4) yields:

$$\ln \frac{k_1^1}{k_1} = \frac{E}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \qquad (23)$$

or

$$\log_{10} \frac{k_1^1}{k_1} = \frac{E}{2.303R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \qquad (24)$$

$$= \frac{E}{4.58} \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \qquad (25)$$

where: R = 1.99 calories/degree C

T_1 and T_2 are absolute temperature, Kelvin.

Equation (23) can be expressed as:

$$\frac{k_1^1}{k_1} = e^A \qquad (26)$$

where: $A = \frac{E}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$

$$= \frac{E}{R} \cdot \frac{(T_2 - T_1)}{T_1 T_2}$$

$= C\ (T_2 - T_1)$ with sufficient approximation.

Hence, Equation (26) becomes

$$\frac{k_1'}{k_1} = \frac{e^{C(T_2 - T_1)}}{\theta^{(T_2 - T_1)}} \qquad (27)$$

where:

$\theta = e^C$ = temperature coefficient

Streeter and Phelps[40] found the value of θ as 1.047 for deoxygenation rate constant. This means that an increase of 1 degree Centigrade increases the velocity of the reaction 4.7 percent and an increase of 10° C. temperature increases the velocity of reaction 58.4 percent. These values of θ were found to apply to a temperature range between 9° C. and 30° C. Moore's[40] experiments revealed that for a temperature range of 5° C. to 20° C., the value of θ was 1.065 and for a temperature range of 0.5° C. to 5° C., the value of θ was 1.145. The value of θ generally used is 1.047 for deoxygenation rate constant and 1.2041 for reoxygenation rate constant.

Similarly, BOD oxidizability can be expressed by the following equation:

$$\frac{L_1}{L} = e^{C_L (T_2 - T_1)} \qquad (28)$$

or by series expansion and omission of higher order terms in "T", Equation (28) becomes

$$\frac{L_1}{L} = 1 + C_L (T_2 - T_1) \text{ (Ref. 41)} \qquad (29)$$

where:

L_1 and L = oxidizabilities of organic matter at temperatures T_2 and T_1 respectively.

C_L = temperature characteristic = 0.02 per degree C in the region of 20° C.[41]

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